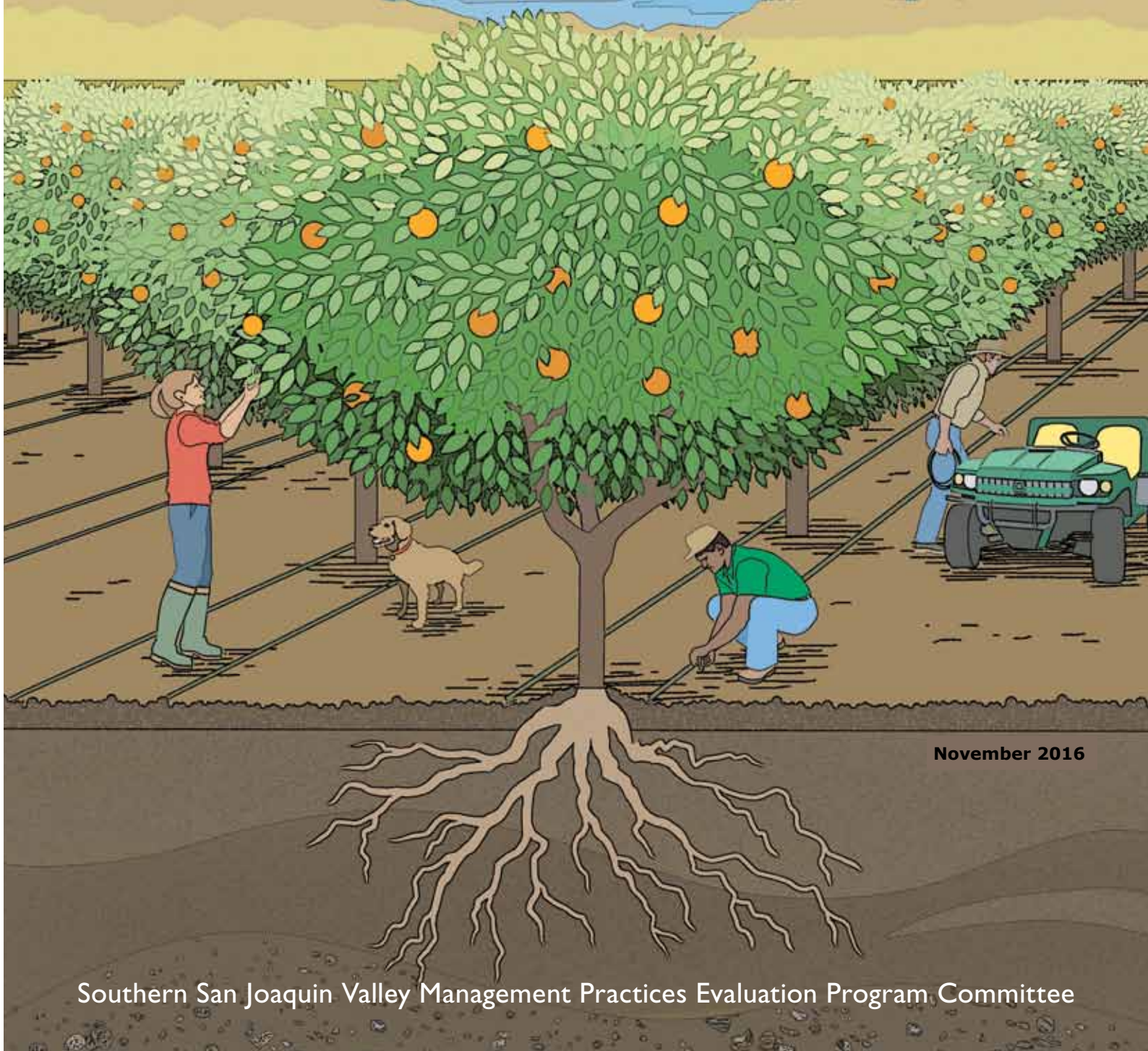


FINAL MANAGEMENT PRACTICES EVALUATION WORKPLAN



November 2016

Southern San Joaquin Valley Management Practices Evaluation Program Committee

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**Southern San Joaquin Valley
Management Practices Evaluation Program Committee**

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LIST OF ABBREVIATIONS

AWMP	Agricultural Water Management Plan
AID	Alta Irrigation District
AW	Applied water
BMP	best management practice
CCA	Certified Crop Adviser
CDFA	California Department of Food and Agriculture
Committee	SSJV MPEP Committee
CIMIS	California Irrigation Management Information System
Crop Reports	County Agricultural Crop Reports
CSU	California State University
CVHM	Central Valley Hydrologic Model
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
DEM	digital elevation model
DWR	California Department of Water Resources
ET	Evapotranspiration
FREP	Fertilizer Research and Education Program
GAR	Groundwater Assessment Report/Groundwater Quality Assessment Report
General Order	Waste Discharge Requirement General Order for the Growers within the Tulare Lake Basin Area that are members of a Third-Party Group, General Order No. R5-2013-0120, as modified by General Order No. R5-2013-0143.
GIS	geographic information system
GMAW	Groundwater Monitoring Advisory Workgroup
GQMP	Groundwater Quality Management Plan
GQTMP	Groundwater Quality Trend Monitoring Program
HRU	hydrological response unit
IWFM	Integrated Water Flow Model
LTILRP	Long-term Irrigated Lands Regulatory Program
MPEP	Management Practices Evaluation Program
MPER	Management Practices Evaluation Report

List of Abbreviations

MRP	Monitoring and Reporting Program
MWISP	Monitoring Well Installation and Sampling Plan
N	nitrogen
NH ₄	ammonium
NMP	Nitrogen Management Plan
NO ₃	nitrate
NUE	nutrient use efficiency
QAPP	Quality Assurance Project Plan
SSJV	Southern San Joaquin Valley
SSURGO	Soil Survey Geographic Database
STATSGO2	State Soil Geographic dataset, updated; supersedes STATSGO
SWAT	Soil and Water Assessment Tool
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TLB	Tulare Lake Basin
TMP	Trend Monitoring Program
UCCE	University of California Cooperative Extension
USDA	United States Department of Agriculture
USDA-NRCS	United States Department of Agriculture Natural Resources Conservation Service
USGS	United States Geological Survey
Central Valley Water Board	Central Valley Regional Water Quality Control Board
WDR	Waste Discharge Requirement
Workplan	SSJV MPEP Workplan

EXECUTIVE SUMMARY

Background

The Tulare Lake Basin (TLB) includes nearly 3 million acres of irrigated cropland and approximately 10,700 growers. It includes four counties (Fresno, Kern, Kings, and Tulare) that account for nearly 50 percent of the State's crop and livestock production value due to the large area of irrigated, high-value crops and the presence of many large dairies. The Long-term Irrigated Lands Regulatory Program (LTILRP), as it applies to the Southern San Joaquin Valley (SSJV, also known as the TLB), is mostly described in General Orders given to water quality coalitions, and in related documentation from the Regional Water Quality Control Board, Region 5 (Central Valley Water Board).

The General Orders for irrigated lands focus on controlling nitrate (NO₃) contamination of groundwater by irrigated agriculture, and require a Management Practices Evaluation Program (MPEP) to evaluate and demonstrate which management practices are effective in protecting water quality, and how their implementation on the landscape effects this protection. To comply with the requirements of their General Order, individual growers in the TLB are organized under water quality coalitions. Under a Coordination Agreement dated November 18, 2014, and updated in November 2015, the following coalitions agreed to implement the MPEP through the Group Option: Kings River Watershed Coalition Authority, Tule Basin Water Quality Coalition, Kaweah Basin Water Quality Association, Kern River Watershed Coalition Authority, Cawelo Water District Coalition, Westside Water Quality Coalition, and Buena Vista Coalition. These coalitions are organized as the SSJV MPEP Committee (Committee), and represent growers irrigating approximately 1.85 million acres of the 3 million-acre TLB. The primary goal of the Committee is to develop and implement an MPEP that meets the objectives of the General Order in a sound, scientific, and efficient manner. This Management Practices Evaluation Workplan (Workplan) describes the planning and implementation of tasks necessary to demonstrate to the Central Valley Water Board which agricultural management practices are effective in protecting water quality, and how these practices have been or will be implemented to effect this protection.

There are no ready-made templates for the MPEP. Although water quality has been regulated for decades, and some of this regulation has been aimed at nonpoint sources, and some at projects involving irrigation, never has such an ambitious program of regulating farming as it occurs across such a large and economically important landscape been undertaken. To pollute groundwater, applied nitrogen (N) must first travel through the crop and soil system, with transit times that might entail months to many decades. Once beyond the root zone, nitrate generally is not influenced by grower actions. Rather, transport is controlled by vadose zone and aquifer properties and conditions. Thus, the effects of today's farming will, in most of the TLB, not begin to influence groundwater quality for a long time. Accordingly, MPEP progress will be demonstrated by documenting increasing frequency of protective practices on the landscape. This allows progress to be demonstrated earlier, as nitrate sources are attenuated, instead of awaiting changes in groundwater quality, which are a) slow in emerging, and b) influenced by many unrelated factors, such as the volume and quality of recharge from other sources. Grower outreach will occur early and often to inform growers of protective practices for specific

irrigated lands settings (unique crop, soil, and management combinations), and to promote implementation of the practices.

The MPEP is one of several components of the General Orders. Following is a summary of how it inter-relates with the other components to achieve the groundwater quality protection goals of the Irrigated Lands Regulatory Program (ILRP):

- Groundwater Assessment Reports lay the groundwork for the ILRP, identifying the location and type of groundwater impairments in an area, along with some of the causes of these impairments.
- Farm Evaluations identify practices in use by growers, and provide an indication of how they change over time.
- Nitrogen Summary Reports relate nitrogen applied by growers (and removed by crops) to other management, crop, and soil information in our diverse landscapes.
- The Groundwater Quality Management Plans prescribe what actions are needed to diminish loss of specific constituents (like nitrate) from crop root zones; these actions are mostly drawn from the MPEP.
- Both the Farm Evaluation and Nitrogen Summary Report help characterize farming as it occurs on the landscape, which is crucial to the assessment of farming's influence on groundwater quality, which must be done as part of the MPEP.

Together with monitoring data from focused field surveys, calibrated modeling results, and long-term groundwater quality trend monitoring, these provide the feedback we need to initiate, assess, and verify progress in protecting groundwater quality.

Approach

Substantial information related to careful management of nitrogen (and the irrigation water that may carry it beyond the root zone before plants can consume it) is available in scientific and extension (outreach) literature, and through the extensive hands-on irrigation and nutrient management expertise of knowledgeable growers and grower advisors. Matching this information to applicable field situations and extending it to additional growers through early outreach, is a priority to make rapid, impactful progress in reducing nitrate loading to groundwater. The MPEP will draw on guidance from industry (e.g., commodities groups), public sector expertise (e.g., University of California Cooperative Extension and Experiment Station, California State University campuses, and the United States Department of Agriculture [especially the Natural Resources Conservation Service]), as well as the coalitions and their membership. Where existing knowledge needs to be supplemented, focused field investigations will be warranted. When this is the case, technical experts can help design, implement, interpret, and summarize field studies so that findings can be used by others to adjust management practices, where necessary. Therefore, key technical experts with deep knowledge and the ability to perform studies to expand this knowledge will be engaged as technical partners. To facilitate this interchange, the

Committee has contracted with a team of agronomists, horticulturalists, plant nutritionists, soil scientists (specialists in management, soil fertility, soil physics, and modeling), and hydrogeologists.

The following are key features of the MPEP technical approach:

- A systematic, scientific approach to evaluating the influence of management practices on water quality in a variety of settings,
- Identification of known protective practices and fast-tracking these to grower outreach to accelerate implementation,
- Prioritization of nitrate sources based on readily available information,
- Identification of significant gaps among known protective practices and means to address these knowledge deficits,
- Where necessary, assessment of performance of field evaluations in representative locations and incorporation of findings into evaluations and outreach,
- Leverage of coalition and other spatial data to assess landscape-level source strength, and
- Allowance for a diversity of tools and specific monitoring and analytical approaches.

The individual components of the technical workflow include the following, and are summarized in Figure ES-1:

1. Inventory known protective practices and fast-track these to early outreach (Sections 2.4 and 3.11).
2. Characterize the root zone (including crops, climate, and irrigation methods that affect it) and sub-root-zone (geology, hydrogeology) of irrigated lands (Section 3.5).
3. Explore and illustrate the relationship between root-zone and groundwater nitrate observations, and thus demonstrate the relevance of root-zone results across the broader landscape for assessment of the level of groundwater protection afforded by various land use and management regimes (Sections 3.6 and 3.9).
4. Quantify actual and minimized loading from root zones by considering existing and alternative management practices (Section 3.6).
5. Establish prioritization criteria by building on those identified in the Groundwater Assessment Reports (GARs). Example criteria include total crop acreage, average nitrogen application rate in the area, and hydrogeologic setting (Section 3.7).
6. Prioritize crops and settings relative to potential influence on groundwater (Number 5). Invest resources, according to priority, to define protective management practices that minimize nitrate leaching (Section 3.7).

7. Assess and/or verify N balances, N surplus, and fate and transport in high-priority systems (including sets of practices) based on existing knowledge (Section 3.6) and, where necessary, focused field studies (Section 3.8).
8. Share results of fate-and-transport assessments through outreach with growers, and assess rate of protective management practice adoption (Sections 3.8, 2.4, and 3.11).
9. At regular intervals, assess adoption of management practices (Section 3.6). Incorporate findings into source modeling to accurately reflect management changes (Number 10; Section 3.10). Employ findings as feedback to outreach to gauge practice acceptability and outreach efficacy (Number 8; Sections 2.4 and 3.11).
10. Use characterization and source information (Numbers 2 and 4) to parameterize the Soil and Water Assessment Tool (SWAT) by employing scientifically based crop-, water-, and nutrient-management model(s). Use fate-and-transport results (Number 7) to calibrate, validate, refine, and update the landscape-level model (i.e., SWAT) (Section 3.10). Use practice-adoption information (Number 9) to assess the performance changes that result from adoption of protective practices.
11. Incorporate refined knowledge about performance and landscape-level output into outreach programs (Number 8; Sections 2.4 and 3.11).
12. Across the broader landscape, relate root-zone results (Number 10) to groundwater quality via a) vadose zone and groundwater modeling, and b) evaluation of groundwater monitoring data from groundwater monitoring networks (e.g., LTILRP trend monitoring wells) (Section 3.9).

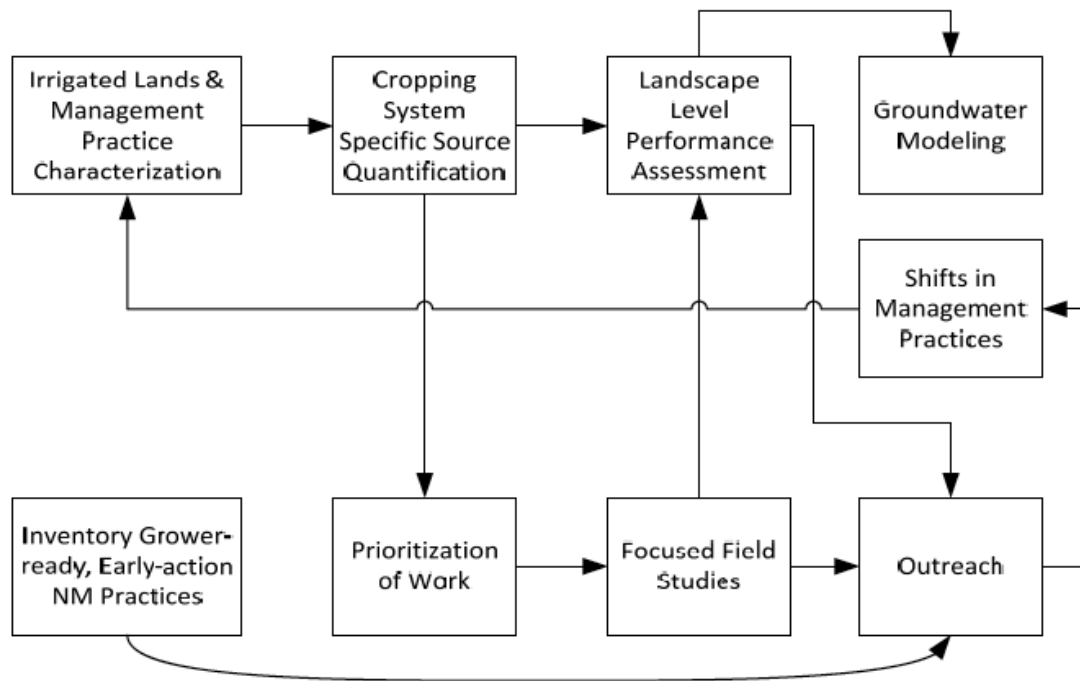


FIGURE ES-1. SUMMARY OF MPEP TECHNICAL WORKFLOW (SEE FIGURE 2-2 FOR ADDITIONAL DETAIL ON THE TECHNICAL WORKFLOW RELATED TO THE ROOT-ZONE)

Grower Outreach

Effective grower outreach related to MPEP results is the key for success of the program. Numerous information resources are available for growers (e.g., United States Department of Agriculture Natural Resources Conservation Service, University of California Cooperative Extension, commodities groups, Certified Crop Advisers, etc.), using a variety of formats (e.g., online tools, targeted mailings, online and paper literature, word-of-mouth, etc.). A diversity of information platforms and communication tools exists among growers and those who have (or can access) the information they need. The SSJV MPEP will seek to leverage these existing resources to provide the following types of information to growers:

- Program and process information, explaining regulatory obligations and how to meet them, schedules, meetings, and where to find information on protective practices,
- Referrals to technical advisors who can assist growers in fitting suites of protective practice to their specific settings and needs,
- New information on protective practices and environmental performance, as it is collected and made available, and

- Peer information from other/neighboring growers regarding crop selection, location, and management, mainly obtained through the coalitions.

The success of outreach will therefore depend on prioritizing practices that growers can use and that have potential to increase levels of groundwater quality protection, and on leveraging the broad range of existing information-sharing resources through collaboration and partnership.

In September 2016, the SSJV MPEP Committee was awarded \$2M through the USDA NRCS Conservation Innovation Grant program. This grant award, combined with match contributions exceeding \$2M, provides part of the funding necessary for successful implementation of this Workplan.



**United States
Department of
Agriculture**

Natural Resources Conservation Service

1 BACKGROUND

The Long-term Irrigated Lands Regulatory Program (LTILRP), as it applies to the Southern San Joaquin Valley (SSJV), (also referred to as the Tulare Lake Basin [TLB] and the MPEP area), is mostly described in General Orders given to water quality coalitions, and in related documentation from the Regional Water Quality Control Board, Region 5 (Central Valley Water Board). The recipients of these General Orders are agricultural water quality coalitions, which are third parties representing groups of growers to respond to the requirements of the General Orders (there are multiple General Orders for irrigated lands throughout the state and one for dairies). Several of the coalitions in the SSJV have agreed to join forces to implement a Management Practices Evaluation Program (MPEP), the planning and implementation of which is one requirement of the General Order for growers within the TLB (hereafter General Order) (Central Valley Water Board, 2014). Several coalitions have formed the Southern San Joaquin Valley Management Practices Evaluation Program (MPEP) Committee (Committee) to respond to this requirement. This Management Practices Evaluation Workplan (Workplan) is a product of that collaborative effort.

The General Order defines the MPEP's overall goal and objectives as follows:

The overall goal of the Management Practice Evaluation Program (MPEP) is to determine the effects, if any, irrigated agricultural practices have on first encountered groundwater under different conditions that could affect the discharge of waste from irrigated lands to groundwater (e.g., soil type, depth to groundwater, irrigation practice, crop type, nutrient management practice).

- *Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas;*
- *Determine if newly implemented management practices are improving or may result in improving groundwater quality;*
- *Develop an estimate of the effect of Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive Officer or as a result of the recommendations by the expert panels by CDFA and the State Water Board, must be provided; and*
- *Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.*

(See General Order pages WDR-31 and MRP-15 for the goal, and page MRP-18 for the objectives.)

1 Background

Further, the General Order invests the third party (i.e., coalitions, in this case working together as the Committee) with the ability to select its own assessment tools, while not making any particular tool mandatory, including groundwater monitoring, as stated in the following:

The workplan must include a scientifically sound approach for evaluating the effect of management practices on groundwater quality. The proposed approach may include:

- *Groundwater monitoring;*
- *Modeling;*
- *Vadose zone sampling; and/or*
- *Other scientifically sound and technically justifiable methods for meeting the objectives of the Management Practices Evaluation Program.*

(See General Order page MRP-20, Section IV.D.)

Since the focus of the MPEP is answering the questions related to management practices, the method or tools to be used are not prescribed by the Central Valley Water Board. The third party is required to develop a workplan that describes the tools or methods to be used to associate management practice activities on the land surface with the effect of those activities on underlying groundwater quality. The Central Valley Water Board anticipates that the MPEP workplan will likely propose using a variety of tools, such as vadose zone monitoring, modeling, and groundwater monitoring.

(See General Order page IS-14, 5th paragraph.)

The General Order also requires Groundwater Quality Management Plans (GQMPs) in certain circumstances, and describes them as follows, with emphasis added to elements closely inter-related to the MPEP):

*The main elements of GQMPs are to A) investigate **potential irrigated agricultural sources of waste discharge to groundwater**, B) review physical setting information for the plan area such as geologic factors and existing water quality data, C) considering elements A and B, develop **a strategy** with schedules and milestones to implement practices to ensure discharge from irrigated lands are meeting Groundwater Receiving Water Limitation III.B, D) develop a **monitoring strategy** to provide feedback on GQMP progress, E) develop **methods to evaluate data collected under the GQMP**, and F) provide reports to the Central Valley Water Board on progress.*

The GQMP is mentioned here because, while it is discussed and required separately within the General Order, the Coalitions' work on management practices, whether this work is triggered by MPEP or GQMP requirements, forms a relatively coherent, unified body of work. That body of work is described in this workplan, without parsing between the two tightly inter-related regulatory vehicles. Coalitions' coordinated approach to management practices is the best way to achieve rapid progress in meeting the goals of the General Order. The inclusion of elements in this integrated approach should not, and does not prevent Coalitions from excerpting them into GQMP documents. The specific focus and timing of outreach discussed in this workplan will be adjusted as needed to respond to commitments in the GQMPs.

Required Outputs and Data Quality for the MPEP and Anticipated Uses of Results

The MPEP is the process by which the coalitions will demonstrate to the Central Valley Water Board which management practices are effective in protecting water quality. The MPEP must produce the following:

- Refined, quantitative assessments of nitrate loading from irrigated lands' root zones, for use in prioritizing investigation and outreach, and in assessing threat to groundwater quality.
- Identification of which management practices are protective of water quality in a variety of settings.
- Early and ongoing outreach to growers to inform and promote implementation of protective practices.
- A technical approach to verifying overall program success in implementation of protective practices and in reduction of nitrogen loading to groundwater.
- A groundwater monitoring approach.
- Inputs to annual reports by coalitions.
- A final MPEP Report.

The level of precision must be sufficient to demonstrate reductions in nitrogen loadings to groundwater.

The MPEP requirement is limited to lands classified "highly vulnerable" with the general understanding that practices that are protective under the most vulnerable conditions are at least as protective under less vulnerable conditions. However, pertinent findings of the MPEP are to be applied, within reason, to other irrigated lands as well. Aside from its geographic importance (with some application to all irrigated lands in the MPEP area), the MPEP has the following distinctive properties and functions:

- It is focused on the surficial portion of the environment where crop production and management decisions affect the movement of constituents of concern off/out of irrigated lands, and potentially into surface streams or groundwater.
- It is aimed at both quantification of pollutant loads and, where necessary, identification of actions that can be taken by growers to reduce the movement of those constituents into surface water or groundwater.
- Within the General Order, the MPEP is the key program to identify protective practices and (sometimes in the context of Groundwater Quality Management Plans) use outreach and education programs to achieve changes in agricultural management that actually improve water quality. As such, the MPEP could reduce pressure on growers to take more costly (and potentially less beneficial) actions, such as intensified and more widespread monitoring of waters, which could include construction of monitoring infrastructure (e.g., monitoring wells) and will ultimately prevent cleanup and abatement orders.

The current General Orders focus on controlling nitrate (NO_3) contamination of groundwater by irrigated agriculture, but the overall program also pertains to other constituents that could be construed as pollutants (e.g., sediment in runoff, salts). Nitrate movement through irrigated lands is therefore the

main focus of this Workplan. If other constituents need to be addressed by growers, such as those that may be required pursuant to Groundwater Quality Management Plans (GQMPs), the MPEP will be updated to serve the same functions for those constituents. At that time, addenda to this Workplan might be required to supplement and update the general approach with specific considerations relative to those constituents. However, the general approach described here, if successful, would otherwise remain intact.

1.1 GENERAL ORDER FOR GROWERS IN THE TULARE LAKE BASIN AREA

The overarching goal of the LTILRP is to protect waters of the State, including surface water and groundwater, from waste discharges (e.g., water containing elevated concentrations of nitrate, salts, and sediments) from irrigated lands. The LTILRP achieves this in the Central Valley through six regional and one commodity-based set of Waste Discharge Requirements (WDRs). General Order No. R5-2013-0120, as modified by R5-2014-0143, is the WDR for discharges from irrigated lands in the TLB area. In simple terms, it requires water quality coalitions to do the following:

1. Understand current water quality conditions (by evaluating surface water and groundwater monitoring results),
2. Determine high-priority groundwater areas (with a Groundwater Assessment Report [GAR]),
3. Understand nitrogen (N) management within the region (with N Management Plans [NMPs]) and report certain components (in a Nitrogen Summary Report),
4. Determine cropping patterns and management practices within the region (with Farm Evaluations),
5. Evaluate and demonstrate which management practices are protective of water quality (with the MPEP), and
6. Extend this knowledge to irrigators so that growers can implement protective practices (also with the MPEP).
7. Document implementation of protective practices to the Central Valley Water Board to enable the Central Valley Water Board to respond appropriately.

This Workplan describes the planning and implementation of tasks related to requirements 5 through 7.

1.2 ENTITY AND AREA DESCRIPTION

The TLB includes nearly 3 million acres of irrigated cropland (the Committee represents growers irrigating approximately 1.85 million acres). It includes four counties (Fresno, Kern, Kings, and Tulare) that account for nearly 50 percent of the State's crop and livestock production value due to the large area of irrigated, high-value crops and the presence of many large dairies. Individual growers in the TLB are organized into water quality coalitions that are considered third parties under the General Order.

The General Order allows a third party to fulfill the MPEP-related requirements through a Group Option. Under a Coordination Agreement dated November 18, 2014 and updated in November 2015, the following coalitions have agreed to implement the MPEP through the Group Option:

- Buena Vista Coalition
- Cawelo Water District Coalition
- Kaweah Basin Water Quality Association
- Kern River Watershed Coalition Authority
- Kings River Watershed Coalition Authority
- Tule Basin Water Quality Coalition
- Westside Water Quality Coalition

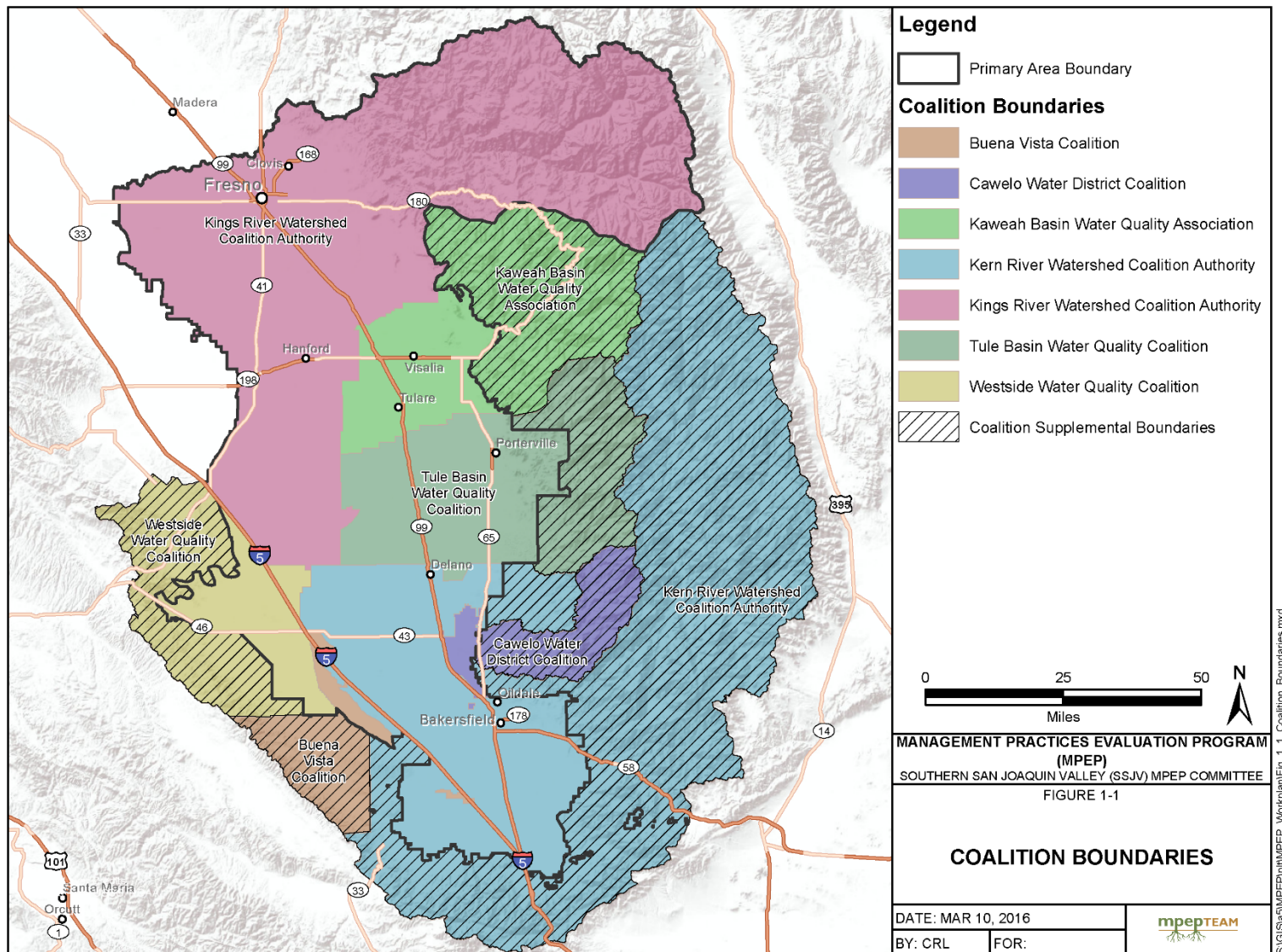
These coalitions are organized as the SSJV MPEP Committee (Committee). Coalition boundaries define the SSJV MPEP area. Coalition boundaries, including the primary and supplemental areas, are shown in Figure 1-1. Note the Kings River Watershed Coalition Authority boundary does not distinguish between its primary and supplemental areas, but that irrigated lands commence along the eastern boundary of the lower-elevation lands along the eastern margin of the valley, and exclude the higher-elevation terrain to the east.

1.3 MONITORING AND REPORTING REQUIREMENTS FOR THE MPEP

The General Order includes a Monitoring and Reporting Program (MRP) to enable the Central Valley Water Board to assess compliance with the General Order and to evaluate whether state waters receiving waste discharges are meeting water quality objectives. The MRP requirements are explained in the following sections of the General Order:

- MRP Section IV.B, Management Practices Evaluation Program
- MRP Section IV.D, Management Practices Evaluation Workplan
- Appendix MRP-2, Monitoring Well Installation and Sampling Plan and Monitoring Well Installation Completion Report.

Table 1-1 displays each MRP requirement and the corresponding Workplan section that addresses each requirement.



S:\GISa5\MPEP\p\MPEP_Workplan\Fig_1_1_Coalition_Boundaries.mxd

FIGURE 1-1. COALITION BOUNDARIES OF THE SSJV MPEP COMMITTEE

TABLE 1-1. MONITORING AND REPORTING REQUIREMENTS FOR THE MANAGEMENT PRACTICES EVALUATION PROGRAM

#	General Order MRP Requirement for the MPEP ¹	Primary Workplan Sections
Section IV.B.1. Objectives		
1	<i>Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas.</i>	Section 3.5, Irrigated Lands Characterization Section 3.6, Source Quantification
2	<i>Determine if newly implemented management practices are improving or may result in improving groundwater quality.</i>	Section 3.10, Landscape-level Performance Assessment Section 3.11, Sharing Findings with Coalition Members Section 3.12, Assessing Adoption, Data Exchange with Coalitions
3	<i>Develop an estimate of the effect of Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive officer or because of the recommendations by the expert panels by CDFA and the State Water Board, must be provided.</i>	Section 3.5, Irrigated Lands Characterization Section 3.6, Source Quantification Section 3.7, Initial Prioritization of Investigations
4	<i>Use the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions) need to be improved.</i>	Section 3.10, Landscape-level Performance Assessment
5	<i>Given the wide range of management practices/commodities that are used within the third party's boundaries, it is anticipated that the third party will rank or prioritize its high vulnerability areas and commodities, and present a phased approach to implement the MPEP.</i>	Section 3.1, Master Schedule Section 3.7, Initial Prioritization of Investigations
Section IV.B.2. Implementation		
6	<p><i>Since management practices evaluation may transcend watershed or third-party boundaries, this Order allows developing a MPEP on a watershed or regional basis that involves participants in other areas or third-party groups, provided the evaluation studies are conducted in a manner representative of areas to which it will be applied. The MPEP may be conducted in one of the following ways:</i></p> <ul style="list-style-type: none"> <i>By the third-party;</i> <i>By watershed or commodity groups within an area with known groundwater impacts or</i> 	Section 1.2, Entity and Area Description

TABLE 1-1. MONITORING AND REPORTING REQUIREMENTS FOR THE MANAGEMENT PRACTICES EVALUATION PROGRAM

#	General Order MRP Requirement for the MPEP ¹	Primary Workplan Sections
	<p><i>vulnerability; or</i></p> <ul style="list-style-type: none"> • <i>By watershed or commodity groups that wish to determine the effects of regional or commodity driven management practices.</i> 	
7	<p><i>A master schedule describing the rank or priority for the investigation(s) of the high vulnerability areas (or commodities within these areas) to be examined under the MPEP shall be prepared and submitted to the Executive Officer as detailed in the Management Practices Evaluation Program Workplan section IV.D below.</i></p>	Section 3.1, Master Schedule
Section IV.B.3. Report		
8	<p><i>Reports of the MPEP must be submitted to the Executive Officer as part of the third party's Monitoring Report or in a separate report due on the same date as the Monitoring Report. The report shall include all data (including analytical reports) collected by each phase of the MPEP since the previous report was submitted. The report shall also contain a tabulated summary of data collected to date by the MPEP. The report shall summarize the activities conducted under the MPEP, and identify the number and location of installed monitoring wells relative to each other and other types of monitoring devices. Within each report, the third party shall evaluate the data and make a determination whether groundwater is being impacted by activities at farms being monitored by the MPEP.</i></p> <p><i>Each report shall also include an evaluation of whether the specific phase(s) of the Management Practices Evaluation Program is/are on schedule to provide the data needed to complete the Management Practices Evaluation Report (detailed below) by the required deadline. If the evaluation concludes that information needed to complete the Management Practices Evaluation Report may not be available by the required deadline, the report shall include measures that will be taken to bring the program back on schedule.</i></p>	Section 3.1, Master Schedule Section 3.13, Regulatory Deliverables
Section IV.B.4. Management Practices Evaluation Report (MPER)		
9	<p><i>No later than six (6) years after implementation of each phase of the MPEP, the third-party shall submit a Management Practices Evaluation Report (MPER) identifying management practices that are protective of groundwater quality for the range of conditions found at</i></p>	Section 3.1, Master Schedule Section 3.13, Regulatory Deliverables

TABLE 1-1. MONITORING AND REPORTING REQUIREMENTS FOR THE MANAGEMENT PRACTICES EVALUATION PROGRAM

#	General Order MRP Requirement for the MPEP ¹	Primary Workplan Sections
	<p><i>farms covered by that phase of the study. The identification of management practices for the range of conditions must be of sufficient specificity to allow Members of the third-party and staff of the Central Valley Water Board to identify which practices at monitored farms are appropriate for farms with the same or similar range of site conditions, and generally where such farms may be located within the third-party area (e.g., the summary report may need to include maps that identify the types of management practices that should be implemented in certain areas based on specified site conditions). The MPEP must include an adequate technical justification for the conclusions that incorporates available data and reasonable interpretations of geologic and engineering principles to identify management practices protective of groundwater quality.</i></p> <p><i>The report shall include an assessment of each management practice to determine which management practices are protective of groundwater quality. If monitoring concludes that management practices currently in use are not protective of groundwater quality based upon information contained in the MPEP, and therefore are not confirmed to be sufficient to ensure compliance with the groundwater receiving water limitations of the Order, the third-party in conjunction with commodity groups and/or other experts (e.g., University of California Cooperative Extension, Natural Resources Conservation Service) shall propose and implement new/alternative management practices to be subsequently evaluated. Where applicable, existing GQMPs shall be updated by the third-party group to be consistent with the findings of the Management Practices Evaluation Report.</i></p>	
Section IV.D.1. Workplan Approach		
10	<p><i>The Workplan must include a scientifically sound approach to evaluating the effect of management practices on groundwater quality. The proposed approach may include:</i></p> <ul style="list-style-type: none"> <i>• Groundwater monitoring;</i> <i>• Modeling;</i> <i>• Vadose zone sampling; and/or</i> <i>• Other scientifically sound and technically justifiable methods for meeting the objectives of</i> 	<p>Section 3.5, Irrigated Lands Characterization Section 3.6, Source Quantification Section 3.7, Initial Prioritization of investigations Section 3.8, Focused Field Studies Section 3.9, A Multi-Pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality</p>

TABLE 1-1. MONITORING AND REPORTING REQUIREMENTS FOR THE MANAGEMENT PRACTICES EVALUATION PROGRAM

#	General Order MRP Requirement for the MPEP ¹	Primary Workplan Sections
	<p><i>the Management Practices Evaluation Program.</i></p> <p><i>Sufficient groundwater monitoring data should be collected or available to confirm or validate the conclusions regarding the effect of the evaluated practices on groundwater quality. Any groundwater quality monitoring that is part of the Workplan must be of first encountered groundwater. Monitoring of first encountered groundwater more readily allows identification of the area from which water entering a well originates than deeper wells and allows identification of changes in groundwater quality from activities on the surface at the earliest possible time.</i></p>	
Section IV.D.2. Groundwater Quality Monitoring – Constituent Selection		
11	<p><i>Where groundwater quality monitoring is proposed, the Management Practices Evaluation Workplan must identify:</i></p> <ul style="list-style-type: none"> • The constituents to be assessed and • The frequency of the data collection (e.g., groundwater quality or vadose zone monitoring; soil sampling) for each constituent [e.g., TDS, nitrate]. <p><i>The proposed constituents shall be selected based upon the information collected from the GAR and must be sufficient to determine if the management practices being evaluated are protective of groundwater quality. At a minimum, the baseline constituents for any groundwater quality monitoring must include those parameters required under trend monitoring.</i></p>	Section 3.9, A Multi-Pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality
Section IV.D.3. Workplan Implementation and Analysis		
12	<p><i>The proposed Management Practices Evaluation Workplan shall contain sufficient information/justification for the Executive Officer to evaluate the ability of the evaluation program to identify whether existing management practices in combination with site conditions, are protective of groundwater quality. The Workplan must explain how data collected at evaluated farms will be used to assess potential impacts to groundwater at represented farms that are not part of the Management Practices Evaluation Program’s network. This information is needed to demonstrate whether data collected will allow identification of management practices that are protective of water quality at Member</i></p>	<p>Section 3.10, Landscape-level Performance Assessment</p> <p>Section 3.12, Assessing Adoption, Data Exchange with Coalitions</p>

TABLE 1-1. MONITORING AND REPORTING REQUIREMENTS FOR THE MANAGEMENT PRACTICES EVALUATION PROGRAM

#	General Order MRP Requirement for the MPEP ¹	Primary Workplan Sections
	<i>farms, including represented farms (i.e., farms for which on-site evaluation of practices is not conducted).</i>	
Section IV.D.4. Master Workplan – Prioritization		
13	<i>If the third-party chooses to rank or prioritize its high vulnerability areas in its GAR, a single Management Practices Evaluation Workplan may be prepared which includes a timeline describing the priority and schedule for each of the areas/commodities to be investigated and the submittal dates for addendums proposing the details of each area's investigation.</i>	Section 3.1, Master Schedule Section 3.7, Initial Prioritization of Investigations
Section IV.D.5. Installation of Monitoring Wells		
14	<i>Upon approval of the Management Practices Evaluation Workplan, the third party shall prepare and submit a Monitoring Well Installation and Sampling Plan (MWISP), if applicable. A description of the MWISP and its required elements/submittals are presented as Appendix MRP-2. The MWISP must be approved by the Executive Officer before the installation of the MWISP's associated monitoring wells.</i>	Section 3.9, A Multi-Pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality
Appendix MRP-2 Monitoring Well Installation and Sampling Plan (MWISP) and Monitoring Well Installation Completion Report (MWICR)		
15	<i>Implementation of the MPEP requires that the third party develop and submit a MWISP to the Executive Officer for approval before installation of monitoring wells. The MWISP or an MWISP for the initial phase if the third-party has chosen to employ a phased approach must be submitted within 180 days after Executive Officer approval of the Management Practices Evaluation Workplan (see Section IV of Monitoring and Reporting Program Order R5-2013-0120, "MRP").</i> <i>Required elements of the MWISP include site information, rationale for number of wells, permitting information, drilling details, health and safety plan, well design, well development, surveying, and monitoring according to the QAPP.</i>	Section 3.9, A Multi-Pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality

Notes:

¹(Central Valley Water Board, 2013)

CDFA: California Department of Food and Agriculture

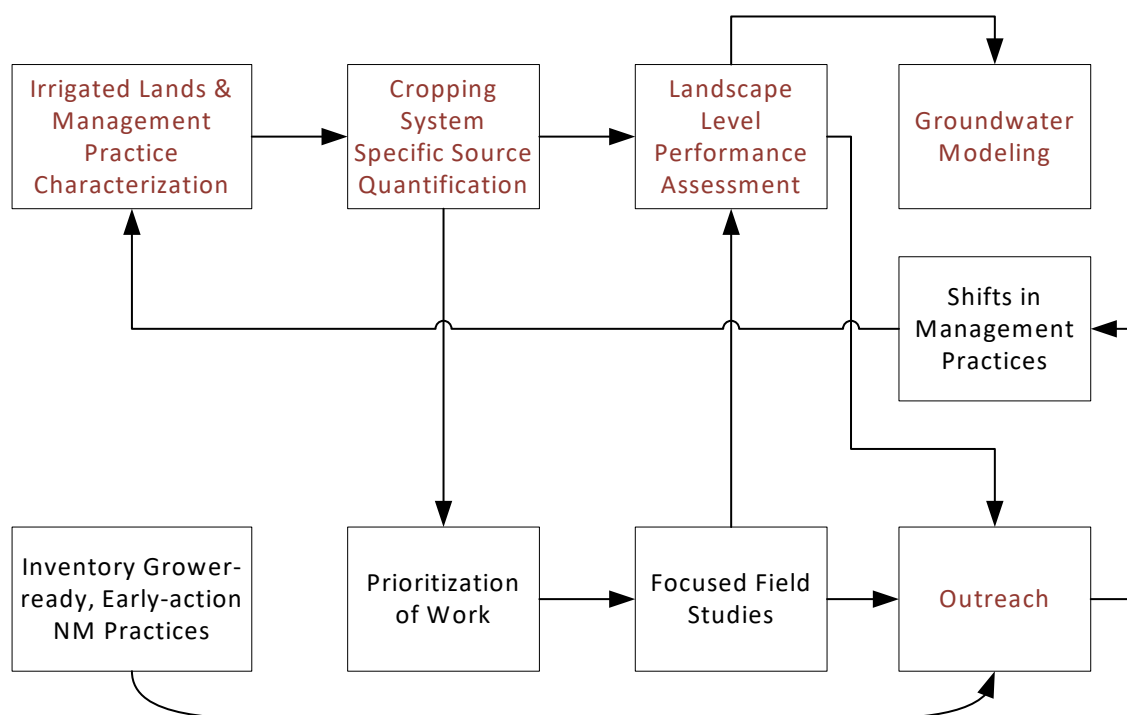
GQMP: Groundwater Quality Management Plan

Natural Resources Conservation Service: Natural Resources Conservation Service

QAPP: Quality Assurance Project Plan

2 PLANNED APPROACH

This section describes the planned regulatory, institutional, technical, and outreach approaches of the Workplan. A simplified schematic (Figure 2-1) illustrates the MPEP process described below.



Compulsory activities
per General Order

FIGURE 2-1. SIMPLIFIED SCHEMATIC OF THE OVERALL MPEP PROCESS

2.1 REGULATORY APPROACH

This Workplan has been developed with guidance from regulatory and technical specialists to create a robust but efficient program that will comply with the General Order and anticipated future groundwater quality protection policy in California. The following sections describe how various aspects of the MPEP comply with the General Order.

2.1.1 SSJV MPEP COMMITTEE GOALS

The primary goal of the Committee is to develop and implement an MPEP that meets the objectives of the General Order in a sound, scientific, and efficient manner. This includes focusing program resources on outstanding questions and/or known problems, minimizing interference with agricultural business and production, and avoiding new and/or expanded regulatory requirements.

Secondary goals include the following:

- Focus resources on actions that will generate the greatest possible water quality protection.
 - Identify, implement, and document implementation of protective management practices (see Section 2.1.2, 2.2). Promote and enhance work by and with technical partners in all the assessment and outreach activities that contribute to success of the MPEP.
 - Recognizing the vastness and diversity of conditions and management across 1.85 million acres of irrigated lands, monitoring needed to verify performance of management practices will be leveraged, by using it to calibrate and verify performance of models that in turn assess landscape-level environmental performance (see Section 2.1.4).
- Engage with Central Valley Water Board staff to build a common understanding and approach to meeting MPEP requirements and Central Valley Water Board goals, and to facilitate resolution of questions and challenges that may arise (Section 2.1.5).
- Recognize and discuss key challenges and opportunities.
 - Example of a key challenge: Management blocks (i.e., fields) and growers are broad, diverse, and numerous; this makes altering outcomes and documenting alterations a very large task, and inherently difficult (Section 2.2.2).
 - Example of a key opportunity: Existing institutional infrastructure that has been developed and harnessed to support growers' production (e.g., United States Department of Agriculture Natural Resources Conservation Service [USDA-NRCS], University of California Cooperative Extension [UCCE], California Department of Food and Agriculture [CDFA], California State University [CSU], and commodity groups) are increasingly focused on environmental performance, and can be powerful partners (Section 2.2.3 and 2.2.4).
- Quantify¹ nitrate loads from irrigated lands across the landscape (Section 2.1.2), and periodically update estimates to document improved performance (Section 2.1.4). This is both a requirement and a means to prioritize work.
 - Where loads are thought to be the most intense or widespread across a crop class, identify and implement mitigating management practices as soon as practicable.
 - Where loads are found to be minimal, document and maintain protective practices. Any regulatory assumptions that these areas are significant sources of nitrate would be worthy of re-examination.
- Exchange information generated through compliance with the General Order (see Sections 2.1.3 and 2.2.2). Relationships being formed and information being gathered by water quality

¹ Quantification of nitrate emanating from root zones is inherently difficult. Results should be considered along with appropriate margins of error, and this should be taken into account when results are used in a regulatory context.

coalitions constitute a new knowledge base and communication pipeline with irrigators. Coalitions will also need the quantitative loading information that will be developed by their MPEP.

- Coordinate activities and methodologies among all irrigated lands coalitions, and dairies, operating under the Dairy General Order. These groups share a number of the Committee's basic tasks, challenges, and opportunities. They also are communicating with the Central Valley Water Board regarding work approaches and findings. Therefore, coordinating activities to the greatest practicable extent will improve work quality and consistency across the board (Section 2.2.1).
- Design and coordinate work to generate broadly useful and beneficial information, so that it is highly valued and supported. The planned work is inherently costly, and much of the technical work has application well beyond the MPEP. This should justify and enable partial, public, and quasi-public funding to support the planned tasks (Section 2.2).

2.1.2 INFLUENCE OF IRRIGATED LANDS ON UNDERLYING GROUNDWATER QUALITY

Management practices are a key factor in understanding the influence of irrigated lands on underlying groundwater quality. Accordingly, this MPEP will provide the following:

- Clear description of how lands are managed.
- Clear description of how management systems perform, including a) identification of areas where altered practices are needed to protect groundwater, and b) areas where practices already in place prove to be protective.
- Identification of protective practices in conjunction with technical partners and growers.
- Intensification and diversification of outreach programs to reach crops affecting large acreages, and those applying the highest rates of nitrogen fertilizer (particularly where efficient removal of applied nitrogen has yet to be adequately documented).
- Timely routing of protective practices into outreach programs to ensure grower understanding, adaptation to each operational and field setting, and adoption.
- Documentation of actions taken to address performance problems and resulting changes in nitrogen fate.
- Projection of the influence of loads from irrigated agriculture on underlying groundwater.

These components will be provided in stages, building on existing data extent, detail, and accuracy, according to the MPEP schedule (Section 3.1).

2.1.3 EXCHANGING DATA WITH COALITIONS AND INFORMING GROUNDWATER QUALITY ANALYSES

As mentioned previously, individual LTILRP coalitions are engaged in complementary activities that can inform the MPEP and allow for more rapid, effective work. Examples of data and work products from the coalitions that are potentially relevant to the MPEP include the following:

- Coalitions' data about the type and location of practices are fundamental to assessing the effects of irrigated agriculture on underlying groundwater. These data might arise from the following sources:
 - Farm Evaluations
 - Nitrogen Summary Reports
 - GARs
 - Trend Monitoring Reports
- Methodology and results (e.g., surface loading, loading to groundwater) from the MPEP can inform Groundwater Quality Management Plans (GQMPs) and other groundwater analyses undertaken by coalitions.

2.1.4 DEMONSTRATING PROGRESS

The Committee will document and demonstrate progress in protecting groundwater from nitrate emanating from irrigated agriculture. Once protective practices for specific irrigated lands settings (unique crop, soil, and management combinations) are identified and implemented under the MPEP, the increasing frequency of those practices on the landscape will be the main evidence of MPEP progress. This is because it is and will likely remain impractical to evaluate and understand landscape-level environmental performance of irrigated agriculture through brute-force monitoring. The number and frequency of observations, and the time and uncertainties associated with their evaluation, are just too great. This limitation was echoed by the Agricultural Expert Panel to the State Board (Agricultural Expert Panel, 2014).

Documentation of this progress will include the following inter-related evidence:

- Documentation of management practices' performance (generic levels of performance, conditioned by the settings in which the practice(s) are implemented [e.g., soils, slope]).
- Outreach to growers to promote implementation of adapted and protective management practices. This includes the following:
 - Specific, usable management information (e.g., crop-specific nutrient management guidelines),
 - Grower adaptation and adoption of protective crop production systems, and

- Documentation of application of specific, protective management practices.
- Assessment of landscape-level impact of program. This includes the following:
 - Development of a verification monitoring framework for landscape-level nitrate loading as a function of management and other factors.
 - Refinements to the framework, including refined model inputs characterizing management and driving the landscape-level assessment of pre-MPEP and a series of post-MPEP conditions. These will be based on the following:
 - Comparisons with results of verification monitoring.
 - Results of management practice field monitoring and evaluation.
 - Comparison of landscape-level performance trends over time
 - Collaborative work with coalitions to assess the impact of changing performance on underlying groundwater.

2.1.5 INVOLVING PARTNERS, RESOLVING ISSUES

Scientific and practical farming and program considerations are the primary basis for MPEP credibility. To succeed, it is crucial to a) incorporate the best knowledge and ideas, and b) clearly explain the approach so that it is broadly understood and accepted as reasonable and sound. As plans are developed, results generated, and challenges considered and addressed, there will be frequent, formal and informal discussions with grower, regulatory, outreach, and technical partners.

Over time, the MPEP may present opportunities to improve upon the manner in which the General Orders have been conceived and/or implemented. The following will be the process for addressing these:

- Develop informative analysis and constructive ideas that contribute to achieving the goals of the LTILRP.
- Engage Central Valley Water Board staff in review of these results and ideas, seeking workable outcomes that address the General Orders' overarching goals and issue(s).

2.2 INSTITUTIONAL APPROACH

Substantial work has been conducted on careful management of nitrogen and the irrigation water that may carry it beyond the root zone before it can be consumed by the plant. Some of this information already exists in the scientific and extension (outreach) literature and some is reflected in the extensive hands-on irrigation and nutrient management expertise of knowledgeable growers and grower advisors. Matching this knowledge to applicable field situations that align with MPEP priorities, and extending it to growers through early outreach, is a way to make rapid, initial progress in the MPEP program. Where existing knowledge needs to be supplemented, focused investigations (field, lab, modeling) will be

warranted. When this is the case, some of these same technical experts can help to design, implement, interpret, and summarize field studies. Therefore, key technical experts with deep knowledge and the ability to focus outreach, and to perform studies to expand what is known, need to be engaged as technical partners. The MPEP will draw on guidance from industry (e.g., commodities groups), public sector expertise (e.g., UCCE, CSU Fresno, USDA-NRCS), the coalitions, and the coalitions' membership.

To facilitate this interchange, the Committee has contracted with a team of agronomists, horticulturalists, plant nutritionists, soil scientists (specialists in management, soil fertility, soil chemistry, soil physics, plant physiology, plant nutrition, agrometeorology, and modeling), and hydrogeologists (specialists in groundwater systems, as well as their management and modeling). The MPEP Team also has extensive experience in environmental applications, including fate and transport of nitrogen, and in regulatory processes as they relate to management of irrigated lands.

An organization chart for the Committee, MPEP Team, and technical partners is included in Appendix A. As shown in Appendix A, the Committee provides overall program leadership to the MPEP Team and technical partners. The Committee Program Manager is Casey Creamer and the Technical Program Manager is John Dickey. The MPEP Team's credentials are included in Appendix B. Some core MPEP activities will be handled by the MPEP Team, but the aforementioned public sector and industry experts will be tapped extensively through collaborative work, so that a broad range of expertise is brought to bear in the program. The following sections provide an additional description of collaboration with these experts.

2.2.1 OTHER MPEP ENTITIES, DAIRIES

Other LTILRP MPEP groups and the Dairy industry are in the midst of similar processes. It makes sense to collaborate, coordinate, and, if possible, share ideas and resources, and employ relatively consistent approaches and tools. This will make all of these programs stronger by providing some level of consistency within the Central Valley, and comprehensibility to the public, the Central Valley Water Board, and member growers. This said, diverse crop, landscape, and operational constraints will justify locally adapted approaches within the overarching, consistent framework.

In addition to sharing technical approaches, it may also be possible to join forces to, for example, facilitate application of surplus organic nitrogen (from dairies) at low rates on non-dairy, irrigated lands, where this improves the overall level of groundwater protection. This type of initiative could have the effect of multiplying the capacity of individual groups' by leveraging the unique resources of each.

2.2.2 COALITIONS AND MEMBERSHIP, GROWER, AND INDUSTRY PARTNERS

Member coalitions are linked directly to the MPEP by their participation in the Committee. Growers are linked to the MPEP through their membership in their coalitions, meetings, communications, and data gathering. Growers will also participate in commodity, other winter, and special-purpose meetings where MPEP findings will be discussed. Presenters primarily will be technical collaborators from public-sector research and extension, as well as private-sector production and grower experts.

Substantial expertise and resources exist in the grower and agricultural services communities (e.g., NRCS, FREP trainings, UC Cooperative Extension, commodities groups, Certified Crop Advisers, etc.). These resources will be used as sources of ideas, knowledge, and data relative to performance of various management practices.

2.2.3 COMMODITIES PARTNERS

In addition to offering technical expertise and a wealth of commodity-specific information, these groups are key partners in procuring funding due to the strength of their relationships with their grower bases; those who pack, ship, sell and purchase produce; CDFA; USDA-NRCS; and political leadership. Also, commodities groups are often networked well beyond California, and thus may alert the MPEP Team to relevant out-of-state experience, knowledge, and expertise that might otherwise be overlooked.

2.2.4 TECHNICAL PARTNERS

California agriculture is productive in part because of the high level of technical expertise in the public and private sectors that support California growers. Traditionally, this expertise has focused on achieving high production and profitability, and that continues. However, over the past 20 to 30 years, the focus on environmental performance of cropping systems has substantially increased, so that most of the expertise needed to tackle questions like nitrate fate and transport in root zones of irrigated lands resides in these same public and private institutions.

We intend to forge energetic and open collaboration with these technical partners, involving them (when and where funding is available) in our efforts to plan and implement the MPEP. This includes, identifying known, protective practices; assessing and quantifying fate and transport through modeling and institutional knowledge; working with cooperating growers; performing focused field studies; explaining sound practices to growers and their advisors; and developing information and tools that facilitate application of practices that protect groundwater quality. Funding for technical work required to inform and perform the MPEP will be provided by the Committee and supplemented by funding procured by partners (e.g., researchers completing relevant studies). Funding sources include USDA-NRCS (e.g., Conservation Innovation Grants), CDFA (e.g., Fertilizer Research and Education Program [FREP]), and commodities groups (e.g., various commodities boards). For most studies under the MPEP, we anticipate that the technical partners will be the principal investigators, but the Committee will lead the overall process.

2.3 TECHNICAL APPROACH

The technical approach is described in detail in Sections 3.5 through 3.10, and 3.12. This section provides an overview of the approach and the relationship of the technical approach to the regulatory and institutional approaches (Sections 2.1 and 2.2).

Features of the approach include the following:

- A systematic, scientific approach to evaluating the influence of management practices on water quality in a variety of settings,

- Identification of known protective practices and fast-tracking these to grower outreach to accelerate implementation,
- Prioritization of nitrate sources based on readily available information,
- Identification of significant gaps among known protective practices and means to address these knowledge deficits,
- Where necessary, assessment of performance of field evaluations in representative locations and incorporation of findings into evaluations and outreach,
- Leverage of coalition and other spatial data to assess landscape-level N source strength, and
- Allowance for a diversity of tools, including monitoring and analytical approaches.

The assembly of these features into a technical process workflow is shown in Figure 2-2 and described in detail in Section 3. The technical workflow can be summarized as follows:

1. Identify known, protective practices, and fast-track these to early outreach (Sections 2.4 and 3.11); see green arrows on Figure 2-2).
2. Characterize the root zone (including crops, climate, and irrigation methods that affect it), and sub-root-zone (geology, hydrogeology) of irrigated lands (Section 3.5).
3. Explore and illustrate the relationship between root-zone and groundwater nitrate observations, and thus demonstrate the relevance of root-zone results across the broader landscape for assessment of the level of groundwater protection afforded by various land use and management regimes (Sections 3.6 and 3.9).
4. Quantify actual and minimized loading from root zones by considering existing and alternative management practices (Section 3.6).
5. Establish prioritization criteria, by building on the prioritization criteria identified in coalition GARs. Example criteria include total crop acreage, average nitrogen application rate in the area, and hydrogeologic setting (Section 3.7).
6. Prioritize crops and settings relative to potential influence on groundwater (Number 5). Invest resources, according to priority, to define protective management practices that minimize nitrate leaching (Section 3.7).
7. Assess and/or verify N balances, N surpluses, and fate and transport (including sets of practices that affect transport) in high-priority systems based on existing knowledge (Section 3.6) and, where necessary, focused studies (Section 3.8).
8. Share results of fate-and-transport assessments through outreach with growers, and assess rate of protective management practice adoption (Sections 3.8, 2.4, and 3.11).

9. At regular intervals, assess level of management practice adoption (Section 3.6). Incorporate findings into source modeling to accurately reflect management changes (Number 10, and Section 3.10). Use findings as feedback to outreach to gauge practice acceptability and outreach efficacy (Number 8, and Sections 2.4 and 3.11).
10. Use characterization and source information (Numbers 2 and 4) to parameterize the Soil and Water Assessment Tool (SWAT) by employing scientifically based crop-, water-, and nutrient-management model(s). Incorporate fate and transport results (Number 7 in this process) to field-check, calibrate, refine, and periodically update the landscape-level model (i.e., SWAT) (Section 3.10). Incorporate practice adoption information (Number 9 in this process) to assess the changes in performance that result from adoption of protective practices.
11. Incorporate refined knowledge about performance into outreach programs (Number 8, and Sections 2.4 and 3.11).
12. Across the broader landscape, relate root-zone results (Number 10) to groundwater quality via a) groundwater modeling, and b) evaluation of groundwater monitoring data from groundwater monitoring networks (e.g., LTILRP trend monitoring wells) (Section 3.9).

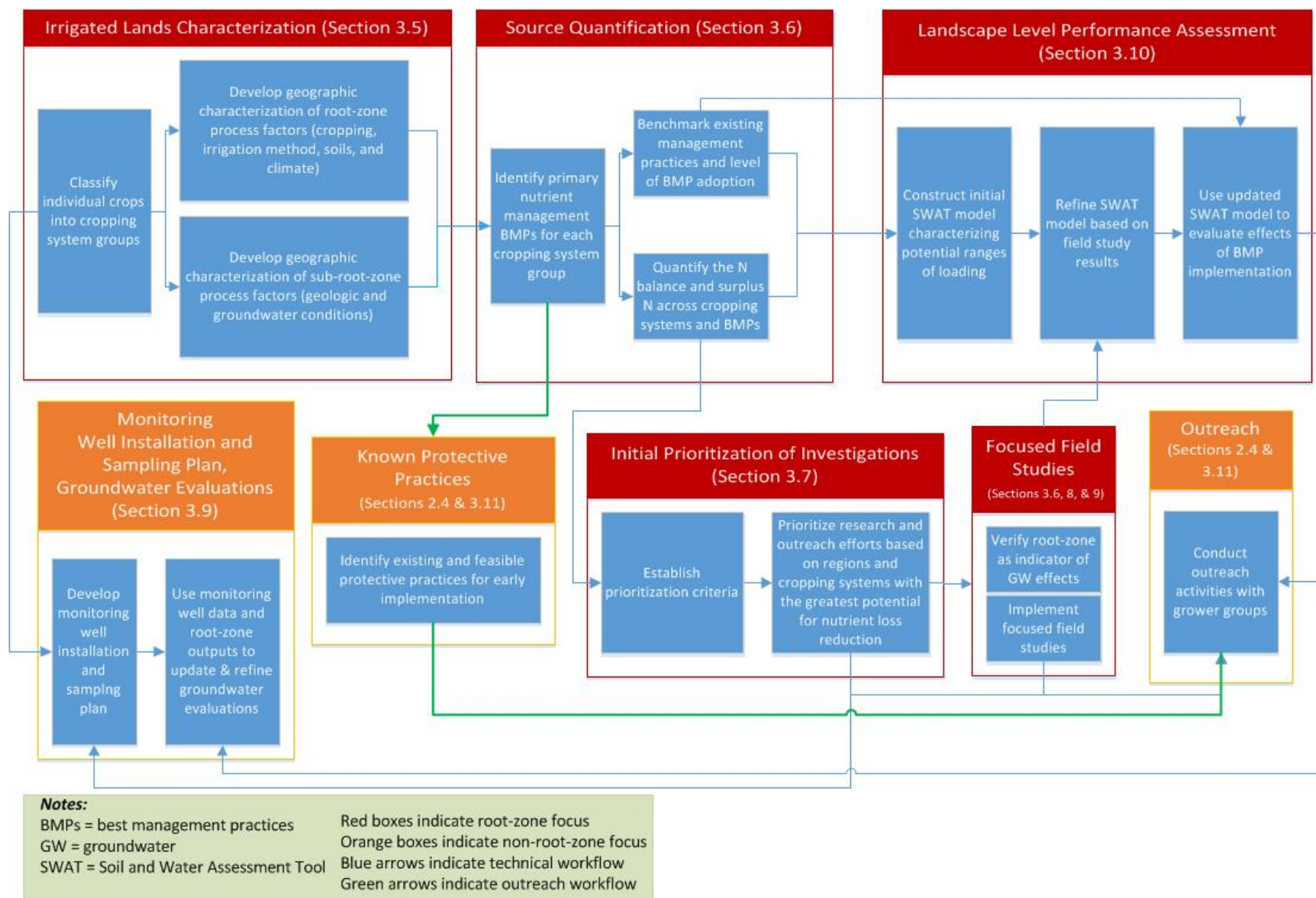


FIGURE 2-2. ROOT-ZONE TECHNICAL PROCESS WORKFLOW FOR THE SSJV MPEP

2.4 OUTREACH APPROACH

Relevant information about crop, soil, and irrigation management can come from many sources and take many forms. The SSJV MPEP will generally seek to leverage existing resources to avoid competition for limited resources and duplication of efforts. To do this, partnerships for data exchange, participation in planned grower meetings, coordination with member coalitions, targeted communications and resources for growers and grower advisors, and web-based tools and information, including links to relevant resources (including MPEP-specific information, where appropriate) will be the main vehicles. Information pipelines and formats to be used in the process are briefly described in this section.

The main themes of information that the SSJV MPEP will focus on include the following:

- Early outreach to rapidly expand implementation of known, protective practices.
- Program and process information, explaining regulatory obligations and how to meet them, schedules, meetings, and where to find information on protective practices.
- Referrals to technical advisors who can assist growers in fitting suites of protective practices to growers' specific settings and needs.
- New and highly relevant information on protective practices and environmental performance, as it is collected and generated.
- Information from growers regarding crop selection, location, and management, mainly obtained through coalitions.

Growers have historically obtained information to guide management decisions from a variety of sources, including the following:

- Information from public-sector experts housed within UCCE, USDA-NRCS, United States Department of Agriculture Agricultural Research Service, CDFA, CSU Fresno, California Polytechnic State University San Luis Obispo, out-of-state cooperative extension services, irrigation and drainage districts, and occasionally other public agencies (e.g., county departments, DWR, California Departments of Fish and Wildlife and Pesticide Regulation, County Agricultural Commissioners, State and Regional Water Boards, Bureau of Reclamation, and the United States Geological Survey (USGS) and Fish and Wildlife Service.
- Private-sector experts housed within commodities groups, Certified Crop Advisers (CCAs), Pest Control Advisers, private institutes (e.g., International Plant Nutrition Institute, Western Growers Association), input manufacturers and vendors, and production cooperatives.
- Other growers, including friends, neighbors, and family members.
- Growers' experiential knowledge bases, which tend to be the most site-specific and best informed about field and management history.

The formats of information exchange among growers vary widely, and include the following:

- One-on-one, word of mouth, or written communication.
- Presentations at grower meetings, technical workshops, and training sessions.
- Online tools and databases, including a Grower/Advisor Webpage, to promote and accelerate understanding and implementation of protective management practices.
- Targeted mailings to memberships of various grower and advisor groups.
- Online and printed newsletters, and online repositories of scientific literature, extension circulars, handbooks, soil surveys, and other references.
- GARs, trend monitoring programs, groundwater quality management plans, and annual reports produced by member coalitions.
- Surveys relating to growers' crop selections, practices, needs, and preferences (e.g., surveys conducted by coalitions to meet Farm Evaluation and Nitrogen Summary Report requirements of the General Order).

A diversity of information platforms and communication tools exists for growers. Many of these resources have been established over long periods, and with levels of investment that the SSJV MPEP cannot realistically hope to match, particularly during its brief, first phase of operation. The success of outreach will therefore depend on prioritizing practices that growers can use and that have potential to increase levels of groundwater quality protection, and on leveraging the broad range of existing outreach resources through collaboration and partnership.

3 PLANNED ACTIVITIES AND SCHEDULE

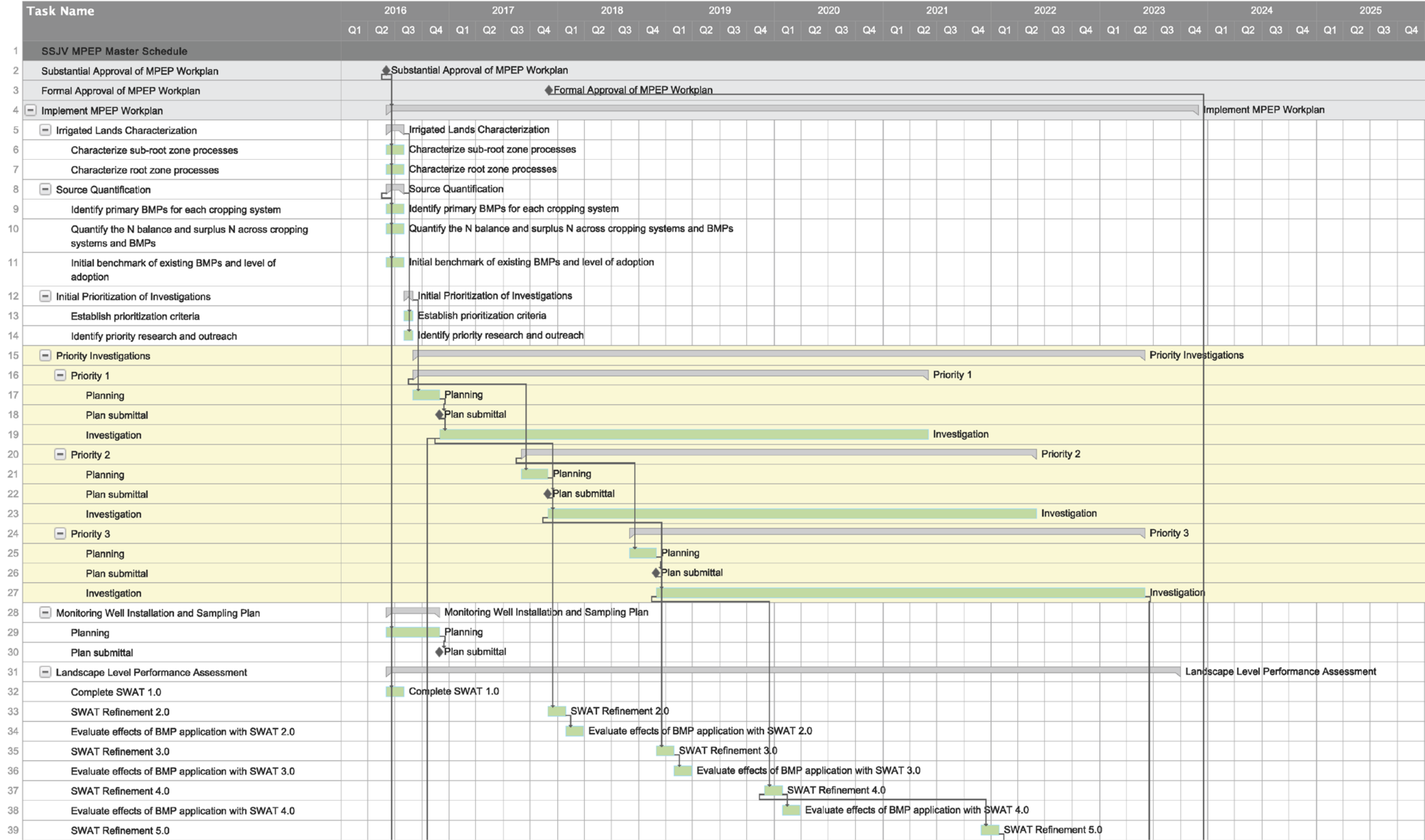
This section describes MPEP activities and the master schedule, including coordination with the Central Valley Water Board, technical partners, coalitions, coalitions' membership, and within the Committee.

3.1 MASTER SCHEDULE

The General Order allows 8 years for development of the MPEP, including 2 years for workplanning and 6 years for implementation of the first phase. This Workplan addresses activities to be completed during the first phase. Subsequent phases are anticipated and will be developed based on results of the first phase. The timeframe for the first phase began in January 2016, when the first GAR submitted by a Committee member (Tule Basin Water Quality Coalition) was approved by the Central Valley Water Board. The General Order requires the Workplan to include a master schedule describing the priority for the investigation(s) of high vulnerability areas (or commodities within these areas) to be examined under the MPEP. Thus, for planning purposes, the master schedule timeline began in January 2016, and extends for 8 years. While this appears to be a long period, it is worth noting that most growers select practices annually, so modifications often take a year to implement and more time to assess. Over a duration of only 6 to 8 growing seasons, substantial planning, investigation, interpretation, outreach, and implementation must occur. Further, implementation progress must be assessed and reported.

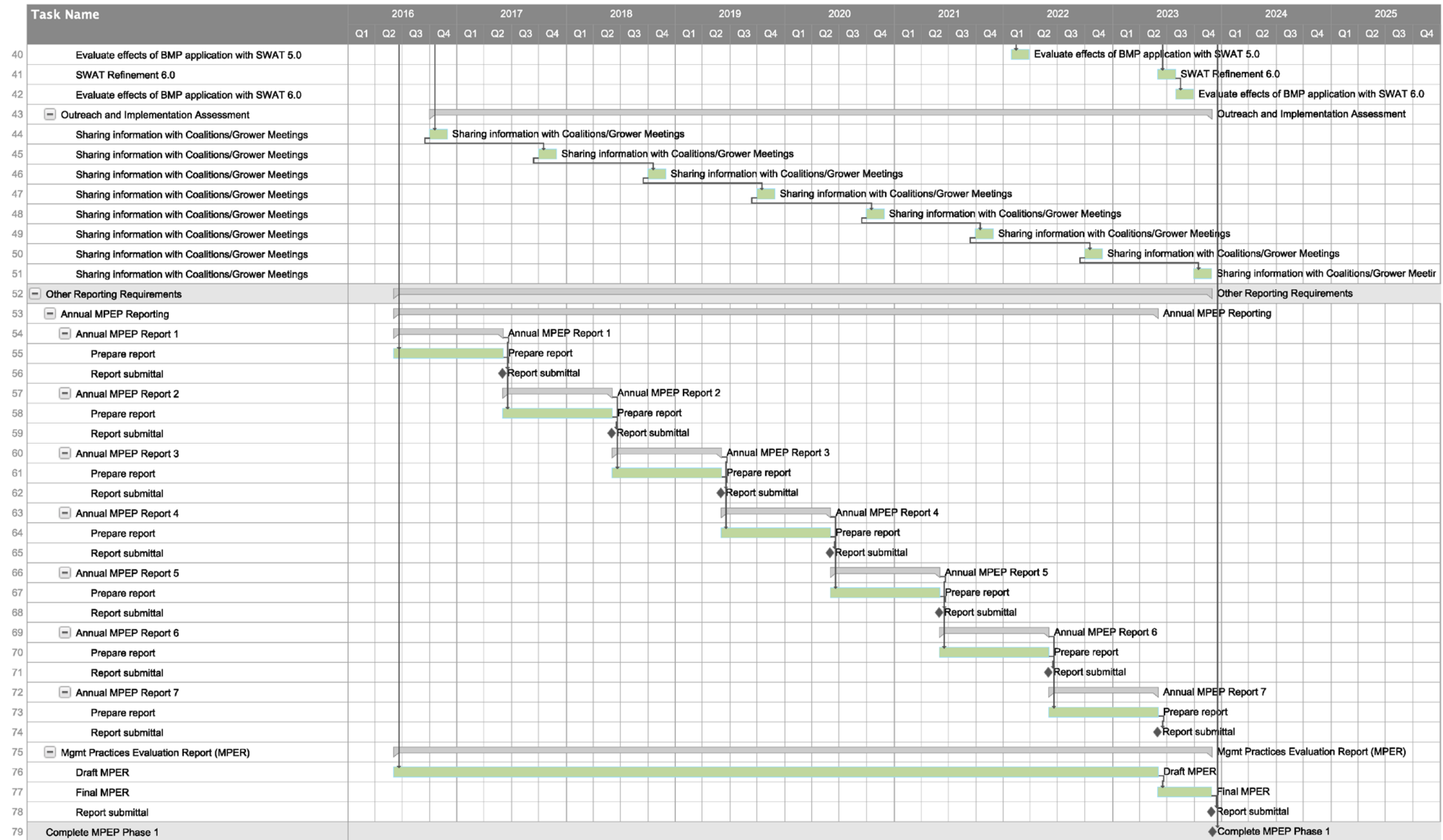
The master schedule is shown in Figure 3-1 and includes implementation of the activities and regulatory deliverables described herein. Although preliminary workplanning for several of the tasks identified in this Workplan began in 2015, significant work will not begin until substantial approval of the Workplan is received from the Central Valley Water Board.

As noted in Section 1, the principal constituent of concern for this Workplan is nitrate, but the LTILRP also pertains to other constituents that could be construed as pollutants (e.g., sediment in runoff, salts, pesticides). If other constituents need to be addressed by growers, such as those that may be required pursuant to GQMPs, the MPEP will be updated to serve the same functions for those constituents in consultation with the affected coalition and the Central Valley Water Board. At that time, addenda to this Workplan might be required to supplement and update the general approach with specific considerations relative to those constituents. However, the general approach described here, along with any updates and improvements that accrue in the meantime, would otherwise remain intact.



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FIGURE 3-1A. MASTER SCHEDULE FOR IMPLEMENTATION OF THE MPEP



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FIGURE 3-1b. MASTER SCHEDULE FOR IMPLEMENTATION OF THE MPEP

3.2 COORDINATION WITH CENTRAL VALLEY WATER BOARD

The Committee recognizes that it is important for the Central Valley Water Board to understand and support the MPEP. Without this support, the essential regulatory compliance function of the program may not be achieved. As such, the MPEP is anticipated to be a two-way, balanced exchange of ideas, information, and perspectives, the outcome of which should ideally enrich the program not only from the standpoints of compliance and acceptability to the Central Valley Water Board and its stakeholders, but also scientifically, so that the actual water quality goals of the program are met in a more timely and effective manner.

Some of the challenges that the Committee and Central Valley Water Board will need to jointly address over the duration of the program include the following:

- **There are no ready-made templates for the MPEP.** Although water quality has been regulated for decades, and some of this regulation has been aimed at nonpoint sources and at some projects involving irrigation, never has such an ambitious program of regulation of farming as it occurs across such a large, diverse, and economically important landscape been embarked upon. Although growers regularly comply with regulation of (for example) the use of agrichemicals, management of farm labor, and food safety, the MPEP program of ensuring skillful use of fertilizers and irrigation water to grow crops in a way that groundwater is protected from nitrate contamination (and ultimately other pollutants identified by the Central Valley Water Board) could be argued to be more multi-faceted and technically challenging than any previous program.

Furthermore, California regulatory programs often set precedents nationally, and sometimes globally. Add to this, 1) the importance of nitrogen in enabling modern, profitable crop production; 2) the fertile setting (one of the world's breadbaskets); 3) the critical need for clean water in Central Valley communities; and 4) the need for growers to remain productive and economically viable; and 5) the importance of food production for human populations to continue to nourish themselves. It is thus quite clear that getting the MPEP right is an unprecedented and high-stakes mission for all involved.

- **The MPEP requires adaptability.** Managing and regulating pollutants like salt and nitrate, particularly in vast and diverse agricultural settings, pose special technical challenges. In recognition of this fact, the Central Valley Water Board itself has convened prolonged and involved discussions with and among stakeholders representing the broadest range of interests and perspectives (e.g., Central Valley Salinity Alternatives for Long-term Sustainability [CV-SALTS]). These processes explicitly recognize the challenge in interpreting, adapting, and applying water quality requirements, orders, regulations, and standards to the complex tasks of protecting beneficial uses from these pollutants.

Unlike many other pollutants, nitrogen and salts are ubiquitous and plentiful. Nitrogen cycles naturally in soil systems, but with elevated intensity when soils are used to producing high yields of irrigated crops. Because no simple solutions (e.g., replacing or avoiding salts and nitrate in

this context) exist, the CV-SALTS process confronts a difficult task. The outcome of that ongoing process will be embodied in a Basin Plan amendment, and will affect related facets of policies, orders, standards, and guidelines. General Orders for the LTILRP, and the MPEP, will need to adapt as this dynamic situation evolves.

- **Limiting nitrate leaching is particularly challenging.** Although some approaches to limiting nitrate movement through soil systems are well established, it is, nevertheless, challenging to manage nitrogen without leaking significant mass from root zones for the following reasons:
 - First, to produce quality products, most crops require that a large mass move through the soil to the growing plants, and that this occur during a large portion of the year when the soil is moist or wet much of the time.
 - Second, nitrate is among the most readily dissolved and mobile of ions, moving with the soil solution when rainfall and/or irrigation moistens the soil.
 - Third, soil nitrogen takes many forms, including various N salts (chemical fertilizers), organic fertilizers, dissolved ions, gasses and aerosols, soil microbes and organic matter, as well as proteins in biomass (plants). There are multiple and kinetically diverse pathways among “pools” of nitrogen held in each form.
 - Fourth, although efficient use of water has the dual advantages of generating more crop per “drop,” and can help to deliver a greater proportion of applied nitrogen to the crop, it does result in a reduced leaching volume, and thus greater leaching concentrations.
 - Fifth, the Central Valley settings in which management decisions are made and take effect are numerous (thousands of growers, tens of thousands of management blocks), and highly diverse (tens of thousands of crop/soil/management combinations), necessitating a large number of site-specific solutions to the general problem of efficient N management.

These complexities are real. To succeed, management and regulatory approaches must recognize these complexities and provide the flexibility to understand and address them, and simultaneously provide for reasonable levels of water quality protection and compliance.

- **Management practices have a delayed impact on groundwater quality.** To affect groundwater, applied nitrogen must first travel through the crop and soil system while avoiding other fates (loss in runoff or lateral subsurface flow, uptake, gaseous loss, and long-term storage in soil microbial biomass and/or organic matter). This might take days to decades, depending on management and the pathway taken. Once clear of the root zone, nitrate is generally no longer affected by any grower’s management of overlying crops and soils. Rather, transport is affected by vadose zone and aquifer properties and conditions. Thus, the first measurable differences in groundwater caused by today’s farming will, in most cases, be observable when the next generation is making management decisions. Much of the nitrate leached in the past is still

largely in the vadose zone. It also follows that, to some extent, future TLB groundwater quality depends on today's practices. Lastly, because crop production cycles vary annually, it generally takes at least a year to study anything under field conditions and learn something new about how protective of groundwater quality a particular set of practices might be.

Yet, it is within these constraints that practices must be adjusted in such a way that farming systems become protective of groundwater. Management practices' performance must be evaluated, and in some instances practices must shift, as the General Order strongly implies that significant progress is expected during a relatively brief timeframe. This leaves the Committee and Central Valley Water Board to develop and agree upon means to anticipate the influence of today's practices on future groundwater quality, and then to use this predictive approach to decide where and how to adjust practices.

- **Groundwater monitoring is an impractical metric to evaluate environmental performance.** The irrigated agricultural landscape of the Central Valley is far vaster and more complex than any that has yet been regulated with this level of intensity by the Central Valley Water Board. It is also managed by thousands of independent parties. At present, environmental monitoring for nitrate (whether in soil or groundwater) is not widely deployed, although records are maintained for management and production parameters that can strongly influence environmental performance. It is practically impossible to monitor this area as we might a more confined site (e.g., a landfill site). Therefore, other means must be identified and developed.

Promising models for establishing efficacy of specific management practices can be seen in the regulation of stormwater, allowing managers and regulators to use these efficacy estimates in assessing environmental performance. At some level, implementation of the practice is accepted as evidence of the related level of efficacy. This allows the planning, implementation, and documentation of water quality protection by knowing the location and levels of maintenance of specific management practices. In the same way, efficacy of protective agricultural practices can be quantified, and performance documented, based on the extent of implementation. In any case, because monitoring is impractical, other means of evaluating performance will be needed (Section 3.10).

- **Data coordination with the LTILRP Process.** Quantifying the effect of practices on underlying groundwater is an MPEP requirement. As part of this assessment, the Committee will quantify the amount of nitrate leached from irrigated lands. The GARs were developed with (at best) preliminary estimates of leaching quantities, so that underlying soil, geologic, and hydrogeologic conditions were heavily emphasized. Therefore, the MPEP will improve the spatial distribution of actual nitrate sources. These improvements should be discussed in advance, so that the new information can properly inform the LTILRP process.

To foster the type of collaborative framework in which such challenges can be understood and addressed in a manner acceptable to the Central Valley Water Board, the Committee envisions a frequent, informal, cooperative effort. After submittal of the Workplan, it would be ideal to hold regular

update meetings on activities, progress, and new information, with presentations by Central Valley Water Board and MPEP staff. During these updates, issues would either be slated for specific action, tagged for communication to the Executive Officer and/or Central Valley Water Board, or tabled for discussion at a specific, future meeting. Items requiring process, technical, and/or regulatory resolutions would be annotated as such. If periodic updates to stakeholder groups are necessary, the Committee will attempt to support Central Valley Water Board staff when such support is requested.

In addition, the Committee will prepare and submit required documents (e.g., Workplan, Master Schedule) for regulatory review. The Committee will make these documents concise, but complete. If the collaborative framework is successful, the Central Valley Water Board should have already seen in another format most, if not all, of the information in the documents.

3.3 COMMITTEE AND TECHNICAL PARTNER COORDINATION

The Committee meets monthly. Activities are aimed at having items ready for Committee consideration at these meetings, timed such that Committee meeting schedules are not a limiting factor to achieving scheduled milestones. When necessary, conference calls and online meetings are held for urgent questions. Committee members participate in the LTILRP processes (e.g., the Technical Advisory Work Group related to N management plans) in a coordinated manner. The coordinated input that emerges is more informed and refined than might otherwise come from the same coalitions participating individually. Information is shared within the Committee by means of a confidential virtual data drive and other online resources, where current schedules, activities, budget status, and other information are maintained.

Technical partners operate on a roughly annual funding cycle, with proposals for much commodity funding due in the fall to allow adequate time to plan and staff for planned field work. To work effectively with these partners, the Committee needs to meet with technical partners early each fall (at the latest) to discuss and pursue funding for priority activities. Planning of outreach activities, which are concentrated during the late fall and winter, must occur during the previous summer. Significant responsibility has been delegated to the MPEP Team to allow for timely discussions with partners, while responsibility for direction, funding, agreements, and commitments is retained by the Committee.

3.4 WORKPLAN COMPLETION AND APPROVAL

As previously noted, the General Order allows 8 years for development of the MPEP, including 2 years for workplanning and 6 years for implementation of the first phase. This timeframe began upon Central Valley Water Board approval of the Tule GAR in January 2016. The Committee will work with the Central Valley Water Board to 1) ensure that the proposed approach is understood and generally acceptable, and 2) to retain the total 2-year workplanning plus 6-year implementation period for development and implementation of the first phase. This ensures that the Committee and the work will not be penalized for expeditious commencement of implementation. This will also increase the quality and quantity of the results implemented in growers' fields and documented in the Management Practices Evaluation Report at the completion of the first phase.

3.5 IRRIGATED LANDS CHARACTERIZATION

Before irrigated lands can be evaluated as a potential source of a constituent (e.g., nitrate, salts, pesticides), the properties and management practices that affect movement of the constituent onto and through the land must be well characterized. “Management” is considered the sum of operations and actions that affect the movement of a constituent through, or off the land. In general, the “land” is considered the sum of material and basic processes affecting the land surface and soil profile downward to a depth below the effective rooting depth (“root zone”) of crops grown on the land surface. This depth varies according to the crop planted. Rooting depth also depends, to a lesser extent (at least in much of the Central Valley), on impediments to rooting, such as hardpans and impaired drainage. The root-zone depth was selected as a focus because, for practical purposes, this is the depth to which land responds to management by growers. Deeper layers may be influenced by irrigated agriculture, but once a constituent moves beyond the root zone, management affects its fate to a far lesser degree, if at all. Hence, the functional root zone is the most appropriate spatial focus for a program aimed at understanding and leveraging the effects of irrigators’ management on water quality.

This section describes how irrigated lands will be characterized so their potential influence on groundwater can be assessed. The “potential influence” includes the following three main components:

- Root-zone processes and factors that affect them including:
 - Cropping.
 - Soil characteristics.
 - Irrigation methods.
 - Climate.
- Sub-root-zone processes and factors that affect them, including:
 - Geologic characteristics.
 - Groundwater conditions.
- Watershed processes and factors that affect them (e.g., topography and hydrography), such as routing of runoff to streams. Note, this is not a focus in this first phase of the MPEP, which is focused on nitrate migration to groundwater.

Required Outputs and Data Quality for Irrigated Lands Characterization and Anticipated Uses of Results

This component of the MPEP technical workflow contributes to meeting the following MRP requirements:

- *Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas.*
- *Develop an estimate of the effect of Members’ discharges of constituents of concern on groundwater quality in high vulnerability areas.*

Results from the Irrigated Lands Characterization feed directly into the Source Quantification (Section 3.6) and A Multi-pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality (Section 3.9).

The following subsections present the planned approach to characterize each major element of irrigated lands within the MPEP area.

3.5.1 CHARACTERIZATION OF ROOT-ZONE PROCESS FACTORS

Root-zone processes and the characteristics that influence those processes must be understood to develop effective management practices that are protective of groundwater quality. The root zone is a buffer between management practices on the land surface and the groundwater beneath. When irrigation water and nutrients are applied at agronomic rates in conjunction with the appropriate management practices for a specific set of conditions, excessive loss of water, nutrients, and other potential contaminants beyond the root zone can be minimized. When water moves beyond the root zone, migration to groundwater may occur over a period ranging from weeks to decades, depending upon the characteristics of the vadose (unsaturated) zone. In this section, the approach for characterizing four primary factors that affect root-zone processes is described.

3.5.1.1 CROPPING

To evaluate the effect of management practices on groundwater quality, cropping systems of the SSJV must be well understood. County Agricultural Crop Reports (Crop Reports) and USDA agricultural statistics are primary sources of current cropping data used for the SSJV MPEP. Each county Agricultural Commissioner submits annual reports to the CDFA. The reports are an excellent source of information on crop type, acreage, yields, and total economic values. These data will be compiled into a database and updated yearly. USDA data are similar and also useful, but may update more slowly. Acreage will be categorized according to specific crop groupings such as nuts, stone fruits, citrus, grapes, forage, cotton, etc., and the general trends of acreage and yields will be used. Table 3-1 is a summary of major crop categories in the SSJV for the years 2013 and 2014, based on Crop Reports from Kern, Kings, Tulare, and Fresno Counties. Table 3-1 also shows the proportions of total irrigated acreage and economic value represented by each category. The 11 crop categories identified in Table 3-1 represent approximately 76 percent of the irrigated acreage and 83 percent of the economic value in the SSJV MPEP area (Figure 3-2). USDA data were compiled for the entire Central Valley and are shown on Figure 3-3, telling much the same story, except in this tabulation, rice (where MPEP requirements are slightly different) and non-alfalfa hay and silage (much of which is being examined carefully under the Dairy General Order), are excluded. Once rice and dairy acreage are excluded, the major crops (making up 75 percent of the acres) for the SSJV and Central Valley are the same.

Crop surveys and land use data from the California Department of Water Resources (DWR) will also be used to evaluate the cropping systems of the SSJV. These use data that are readily available and spatial, but are typically outdated. However, DWR is developing capacity to map crops annually and comprehensively. These types of data will be used in conjunction with crop reports to characterize cropping patterns as they occur spatially across the landscape. The spatial analyses and Soil and Water Assessment Tool (SWAT) models will use spatial cropping data along with other (soil, topographic, climatic, and management) parameters to evaluate the influence of management practices. In addition, Farm Evaluation data will be used when available in mid-to-late 2016.

TABLE 3-1. TWO-YEAR AVERAGE ACREAGE AND VALUE BY CROP CATEGORY IN THE SOUTHERN SAN JOAQUIN VALLEY (SSJV) BASED UPON THE 2013 AND 2014 COUNTY CROP REPORTS

Category ¹	County				Total Acreage ² and Proportion of Total Irrigated Lands in the SSJV ³		Total Value (\$1M) and Proportional Value of Total Irrigated Lands in the SSJV ³	
	Kern	Kings	Tulare	Fresno				
	Acres (1,000)							
Fruit and Nuts - Total	445	100	349	608	1,503	46%	\$11,378	72%
Almond	173	18	44	166	402	12%	\$2,605	17%
Grapes	106	7.5	63	203	379	12%	\$3,644	23%
Pistachio	89	19	44	44	197	6%	\$1,151	7%
Citrus	60	0	124	42	226	7%	\$1,945	12%
Stone Fruit	1.8	7.5	34	39	82	3%	\$930	6%
Tomatoes	14	34	0	105	153	5%	\$699	4%
Walnuts	0.8	14	40	9	64	2%	\$404	3%
Field Crops - Total	273	281	242	183	981	30%	\$1,695	11%
Cotton	40	89	15	55	200	6%	\$594	4%
Silage ⁴	89	114	142	37	382	12%	\$459	3%
Alfalfa ⁴	113	47	71	53	284	9%	\$546	3%
Wheat ⁴	31	31	14	38	115	4%	\$96	1%
Subtotal of Identified Crops	718	381	591	791	2,484	76%	\$13,073	83%
Total Irrigated Lands ^{5,6}	873	472	913	1,008	3,266		\$15,722	

All data from the 2013-2014 County Agricultural Crop Reports.

¹Categories selected to represent crops grown on approximately 80 percent of total irrigated lands in the SSJV MPEP project area.

²Sum of the following counties: Kern, Kings, Tulare, and Fresno.

³Percentages are rounded and may not sum exactly.

⁴A significant portion of these crops is irrigated with dairy effluent. These fields are covered under the Dairy General Order, not the LTILRP.

⁵Sum of the main County Agricultural Crop Report categories. The main categories are fruit and nut, seed crops, field crops, vegetable crops, and nursery crops.

⁶Note that these acreages are for counties covered by coalitions, and include areas not represented by the Committee. The Committee represents 1.85 million acres of irrigated lands with a very similar, proportional crop mix.

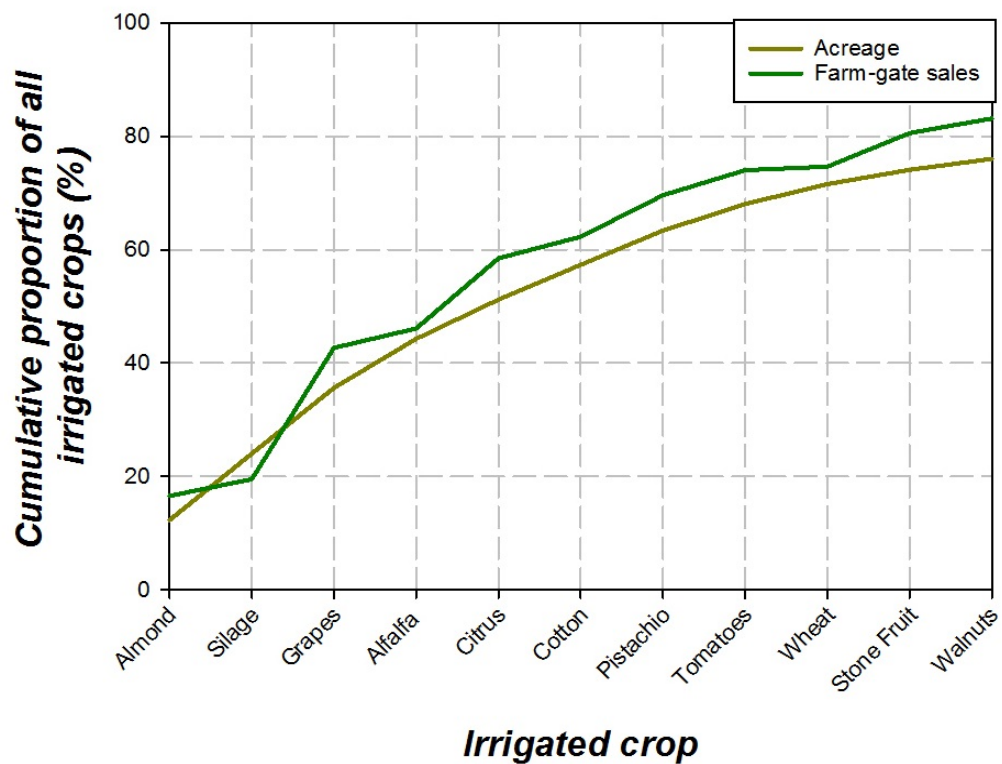


FIGURE 3-2. TWO-YEAR AVERAGE ACREAGE AND VALUE BY MAIN CROP CATEGORY IN THE SOUTHERN SAN JOAQUIN VALLEY BASED UPON THE 2013 AND 2014 COUNTY CROP REPORTS FOR KERN, KINGS, TULARE, AND FRESNO COUNTIES

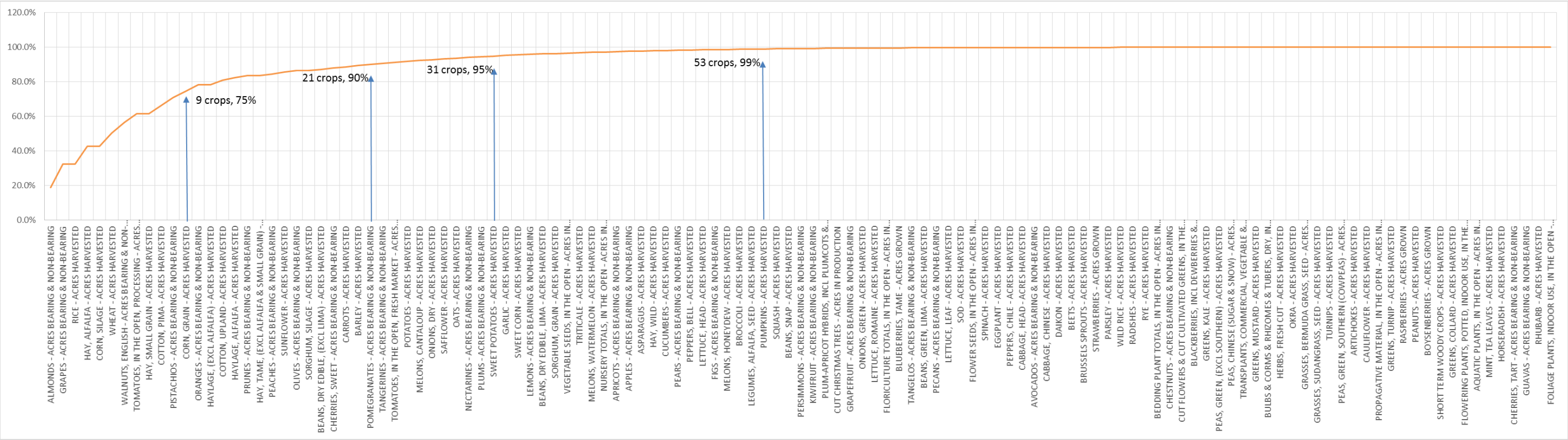


FIGURE 3-3. PLOT OF ALL CROPS CLASSIFIED IN THE MAJOR CENTRAL VALLEY COUNTIES EXCEPT RICE AND NON-ALFALFA HAY AND SILAGE, A TOTAL OF 4.75 MILLION ACRES.

3.5.1.2 SOIL CHARACTERISTICS

To understand the soil characteristics that affect movement of constituents of interest (e.g. nitrate, salts, and pesticides) through root zones in the SSJV, a comprehensive dataset is required. The SSJV MPEP will use the USDA-NRCS Soil Survey for this purpose. The USDA-NRCS Soil Survey data consist of two main databases known as the Soil Survey Geographic Database (SSURGO), and the State Soil Geographic dataset (STATSGO2). The databases consist of georeferenced vector data, tabular data, and information about creation of the data (metadata). The data are available via Web Soil Survey². Overall, STATSGO2 is more generalized than SSURGO. The spatial data are linked to attribute tables of tabular data consisting of measurements or estimates of physical and chemical soil properties and soil interpretations. These data will be used within a geographic information system (GIS) in conjunction with other relevant data to spatially classify important parameters for management practices. The soils data will also be incorporated into the hazard indices and models of fate and transport for further evaluation and quantification of certain management practices. In addition, the Soil Agricultural Groundwater Banking Index (SAGBI) may be used to understand soil characteristics throughout the SSJV.

Soil properties that affect water and nitrate movement through the root zone and beyond include soil texture, structure, salinity, available water-holding capacity, hydraulic conductivity, depth to the water table, and restrictive layers. Such properties are embodied in index and model frameworks, and employed when planning site-specific research and monitoring. They can and often do inform management. Facilitating grower access to soil data and interpretations in usable formats is another way that the MPEP can work with technical partners (NRCS, UCCE) to better inform grower decisions.

3.5.1.3 IRRIGATION METHODS

Irrigation methods are another consideration when evaluating management practices. Irrigation efficiency is the amount of irrigation water that is beneficially used divided by the total amount of irrigation water applied (Burt and Styles, 2011); distribution uniformity describes the uniformity of water applied across a given field. According to Burt and Styles (2011), “beneficial uses” include crop evapotranspiration, salt removal, climate control, soil preparation, etc. and “non-beneficial uses” include excess deep percolation (over and above the quantities required for beneficial uses), excessive tailwater flows, etc. The method of irrigation has a strong influence on the level of distribution uniformity and irrigation efficiency that is achievable under a given set of management conditions and is an appropriate metric to broadly characterize the potential for excess water and nutrient losses from the root zone.

Growers in the SSJV use many different irrigation methods. Table 3-2 shows the three main categories of agricultural irrigation systems in the SSJV and the variations within each category.

² Web Soil Survey provides soil data and information for more than 95 percent of the nation’s counties. The site is updated and maintained online as the single authoritative source of soil survey information. It can be accessed at <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.

TABLE 3-2. SUMMARY OF AGRICULTURAL IRRIGATION SYSTEMS USED IN THE SOUTHERN SAN JOAQUIN VALLEY

Surface Irrigation	Sprinkler Irrigation	Micro Irrigation
Furrow	Hand lines	Drip
Border strip	Wheel lines	Microspray
Level basin	Solid-set	Subsurface drip
	Linear move	
	Big guns	

When managed and operated correctly, most irrigation systems are theoretically capable of obtaining reasonable irrigation efficiencies. Surface irrigation is generally considered to be “less efficient” than sprinkler or micro irrigation, but there can be wide ranges in efficiency within each method depending upon field-specific irrigation system design and management (and also field-specific variables, including soils). The cropping systems of the SSJV continue to shift from annual row crops such as corn and cotton to permanent fruit and nut crops such as almonds, pistachios, and grapes. These permanent crops most commonly use micro irrigation, although some are still surface irrigated. To develop a description of management practices, an inventory of irrigation systems used in the SSJV is needed. DWR irrigated lands spatial data again contain somewhat outdated mapping of irrigation systems. Spatial data layers will be developed from these data and incorporated into GIS analyses for use in the SWAT model (Section 3.10).

The SSJV MPEP will evaluate the following data sources on irrigation methods:

- **GARs.** Several of the GARs developed by Committee members include information on irrigation systems within the SSJV. The GARs will be an important data source for the MPEP.
- **LTLRP Farm Evaluation Surveys.** Growers in the SSJV are required to complete annual Farm Evaluation surveys beginning in 2016. These surveys include information on general farm practices, irrigation wells, field specific evaluations, and a farm map. The irrigation practices section of the survey requires growers to select a primary and secondary irrigation method from the following: drip, microsprinkler, sprinkler, border strip, furrow, surface (level basin), or not irrigated. Once compiled, this information can enhance existing data regarding current irrigation methods in the SSJV. Because this data will not be available for evaluation and processing until mid-to-late 2016, other data sources will be required until that time.
- **Agricultural Water Management Plans (AWMP).** Agricultural water suppliers that provide water to more than 25,000 acres were required to submit AWMPs to DWR by December 31, 2015. These plans include information characterizing supplies and uses, and often include information on irrigation methods used by the suppliers’ customers. The irrigation method information

provided in these plans is potentially a source of data on a district-by-district basis. The SSJV MPEP will investigate this option as a potential data source.

- **DWR Irrigation Surveys.** DWR conducted irrigation method surveys across the state in 1991, 2001, and 2010. Irrigation methods were categorized into three groups associated with 20 crop categories, and were summarized over 10 regions of the state including the Tulare Lake region. The surveys relied upon voluntary, grower-supplied information and are not spatially comprehensive. However, irrigation method data were captured for 408,000 irrigated acres in the Tulare Lake region in the 2010 survey, an ample sampling. This database will be evaluated as a potential source of irrigation method information. While it cannot provide subregional information across the SSJV, it will be a helpful complement to Farm Evaluations and AWMPs.

In addition, technical collaborators, particularly NRCS, CCAs, and vendors, work closely with growers on irrigation system configuration and operations. The MPEP can leverage these resources and, where necessary, support and enhance initiatives that facilitate retention of nitrogen in root zones for crop uptake.

3.5.1.4 CLIMATE

Climate affects water and nutrient management through its impact on crop growth and root-zone hydrology. Data such as air temperature, relative humidity, wind speed, solar radiation, and precipitation are needed to provide a climate context for management practices (e.g., irrigation scheduling), and to support the simulation of root-zone process. Climate is monitored at multiple weather stations across the MPEP area, and these monitoring results will be used. Gridded weather data across the Central Valley are also available from DWR and will be evaluated as a potential source of climate data inputs to the SWAT model.

3.5.2 CHARACTERIZATION OF SUB-ROOT-ZONE PROCESS FACTORS

Sub-root-zone processes partially control how management of irrigated lands influences the migration of water and solutes in the unsaturated and saturated zones. Controlling factors include hydraulic conductivity, the presence and spatial extent of lower permeability units, and depth to water. In this section, the approach for characterizing these sub-root-zone process factors is presented. This discussion is organized in two subsections: geologic characteristics and groundwater conditions.

Sub-root-zone conditions also influence prioritization and outreach by providing an indication of localized underlying groundwater quality and the likelihood and speed of transport to groundwater.

3.5.2.1 GEOLOGIC CHARACTERISTICS

The spatial distribution of sediments and their physical properties (e.g., hydraulic conductivity), including the presence and extent of lower permeability units, are influenced by the geologic setting. Coalition GARs provide detailed data and information on this topic, as summarized in the following discussion.

The MPEP area is located in the Tulare Lake Hydrologic Region at the southern end of the San Joaquin Valley, a structural trough filled with interlayered sediments of sand, gravel, silt, and clay derived from erosion of the Sierra Nevada on the east and the Coast Range mountains on the west. DWR (2003) defines several groundwater subbasins of the San Joaquin Valley Groundwater Basin in the primary MPEP area. Subbasins include the Kings, Kaweah, Tulare Lake, Tule, and Kern County (Figure 3-4).

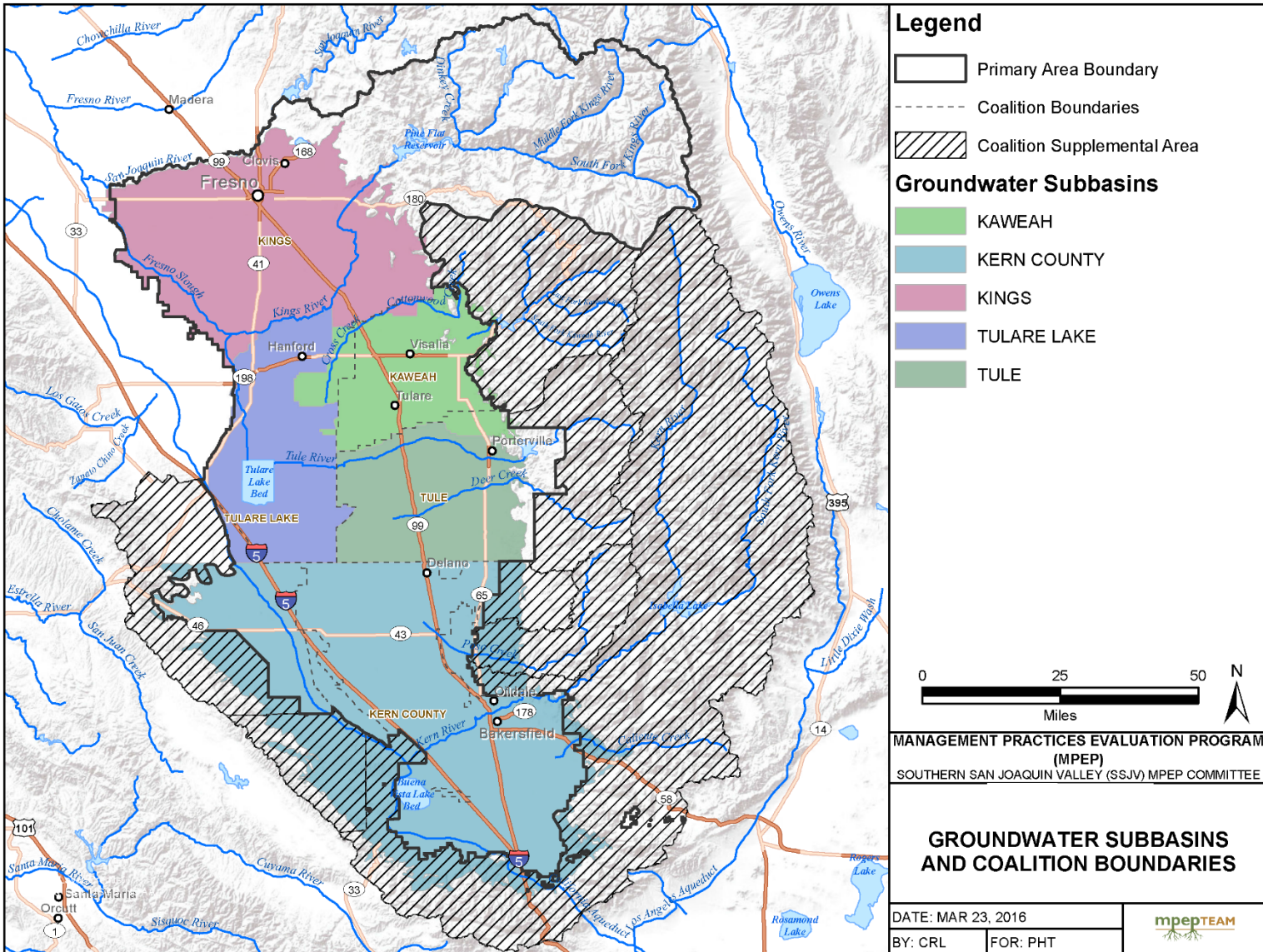


FIGURE 3-4. GROUNDWATER SUBBASINS AND COALITION BOUNDARIES

The valley floor within the SSJV consists of alluvial and basin fill sediments extending vertically for thousands of feet, flood plain deposits of major rivers, and lacustrine and marsh deposits. The lacustrine and marsh deposits crop out in the San Joaquin Valley beneath the Buena Vista, Kern, and Tulare Lake beds (4Creeks, 2015). Sediment texture varies in the east-west direction across the valley. Thick alluvial fans of generally coarse texture occur along the margins (particularly the eastern margin) of the valley. The alluvial fans on the eastern side of the valley reflect the granitic parent rocks of the Sierra Nevada (Faunt, 2009). Sediments in the western San Joaquin Valley are finer-grained compared to those along the east side. Also, the western deposits are underlain by the Corcoran Clay member of the Tulare Formation. The Corcoran Clay is a low-permeability, aerially extensive, lacustrine deposit (Johnson et al., 1968) as much as 200 feet thick (Davis et al., 1959). It divides the groundwater-flow system of the western San Joaquin Valley into an upper, semi-confined zone and a lower, confined zone (Williamson et al., 1989; Belitz and Heimes, 1990; Burow et al., 2004). The Corcoran Clay formed in the finer-grained shales and marine deposits of the Coast Range (Faunt, 2009). The extent of and depth to the top of the Corcoran Clay are illustrated in Figure 3-5. In Kern County, the Corcoran Clay is considered to have generally higher permeability, and does not function as a continuous aquitard or barrier to vertical flow (Provost & Pritchard Consulting Group, et. al., 2015). The USGS Central Valley Hydrologic Model (CVHM) (Faunt, 2009) texture model highlights these characteristics (Figure 3-6), showing a greater percentage of coarse-grained materials in the Corcoran Clay sections that occur in the Kern County Subbasin.

Sediment texture correlates to hydraulic conductivity and, therefore, to the travel time through the unsaturated zone and the saturated portion of the aquifer. Thus, coarse alluvial fan materials (e.g., on the east side of the valley) are generally more permeable than finer textured deposits (e.g., the fans of the Coastal Range). The San Joaquin, Kings, Tule and Kaweah Rivers have cut through the deposited materials, leaving generally coarser alluvium with higher permeability. These zones more readily transmit water and dissolved constituents (GEI, 2014). Figure 3-7 shows the percentage of coarse-grained deposits for the 0-to-50-foot depth; coarser deposits are prevalent in the northeastern portion of the Kings Subbasin and in the central and southern portions of the Kern County Subbasin, while in the western portion of the SSJV, finer-grained materials tend to predominate.

The following describes how the SSJV MPEP will further evaluate sub-root-zone factors:

- **Hydraulic Conductivity.** Hydraulic conductivity varies significantly throughout the SSJV and influences infiltration rates and groundwater flow, which in turn control how rapidly water at the land surface moves through the unsaturated zone to the saturated part of the groundwater system (Provost & Pritchard Consulting Group, et. al., 2015).

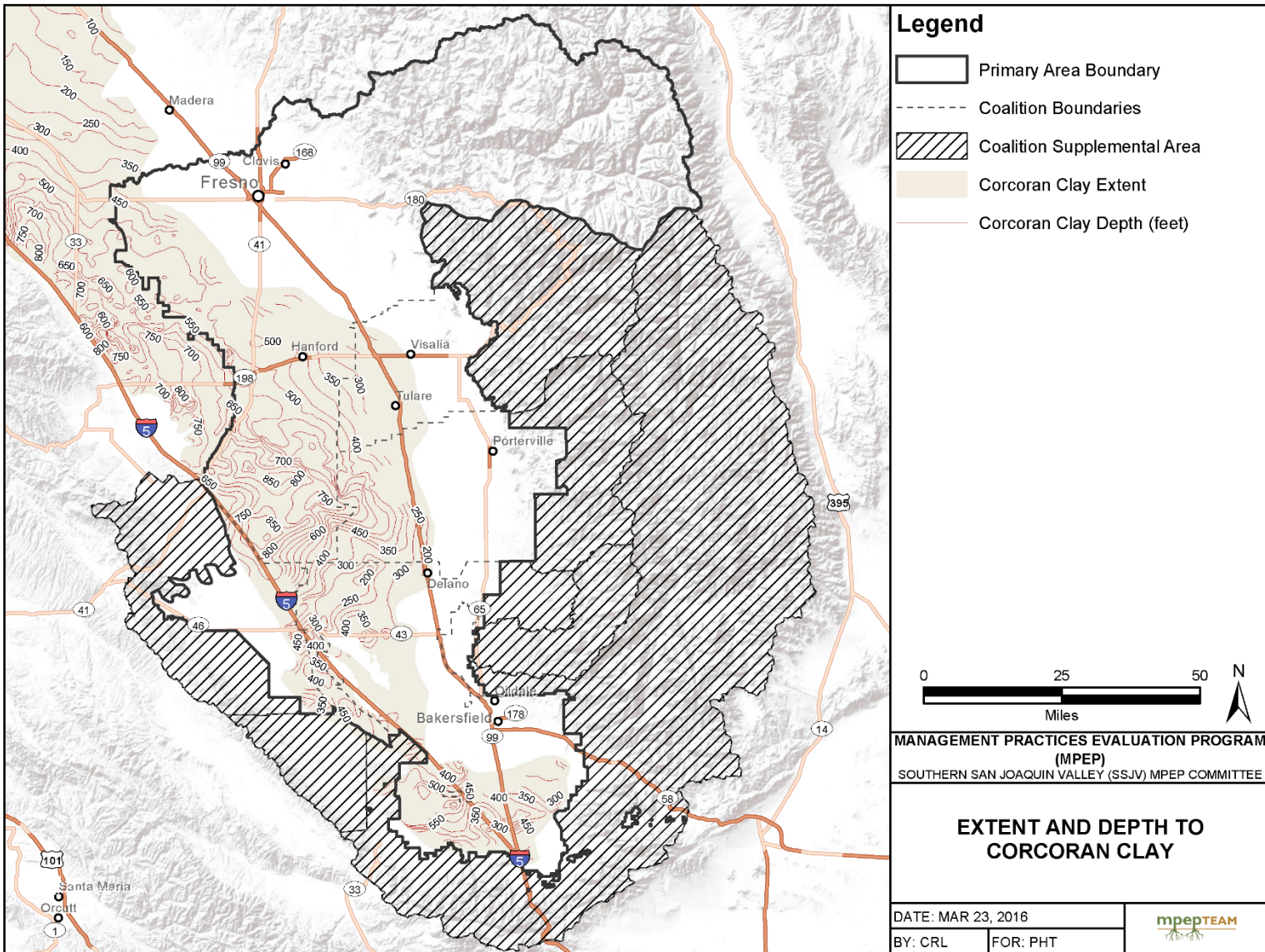


FIGURE 3-5. EXTENT AND DEPTH TO CORCORAN CLAY

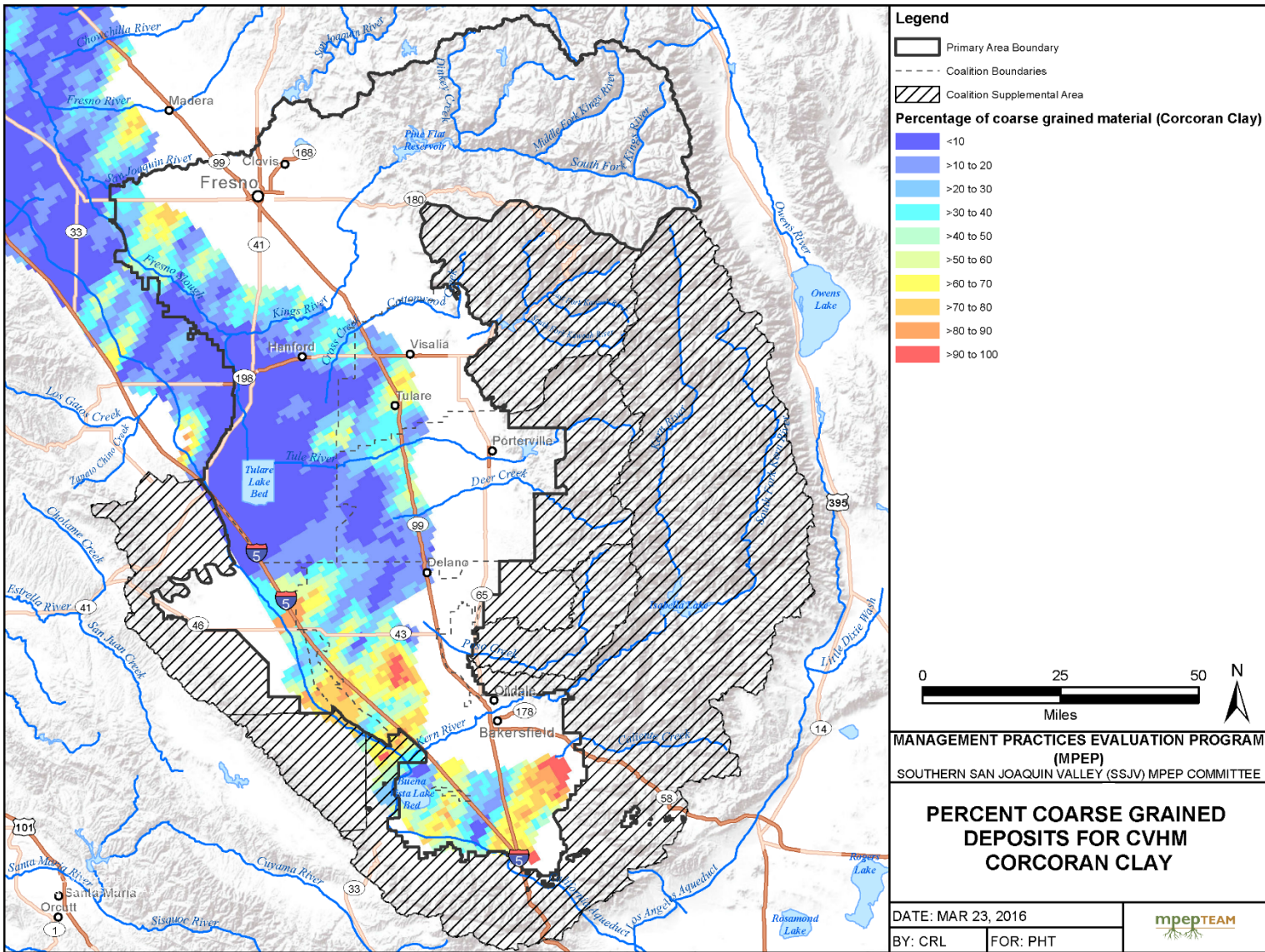


FIGURE 3-6. PERCENT COARSE GRAINED DEPOSITS FOR CENTRAL VALLEY HYDROLOGIC MODEL CORCORAN CLAY

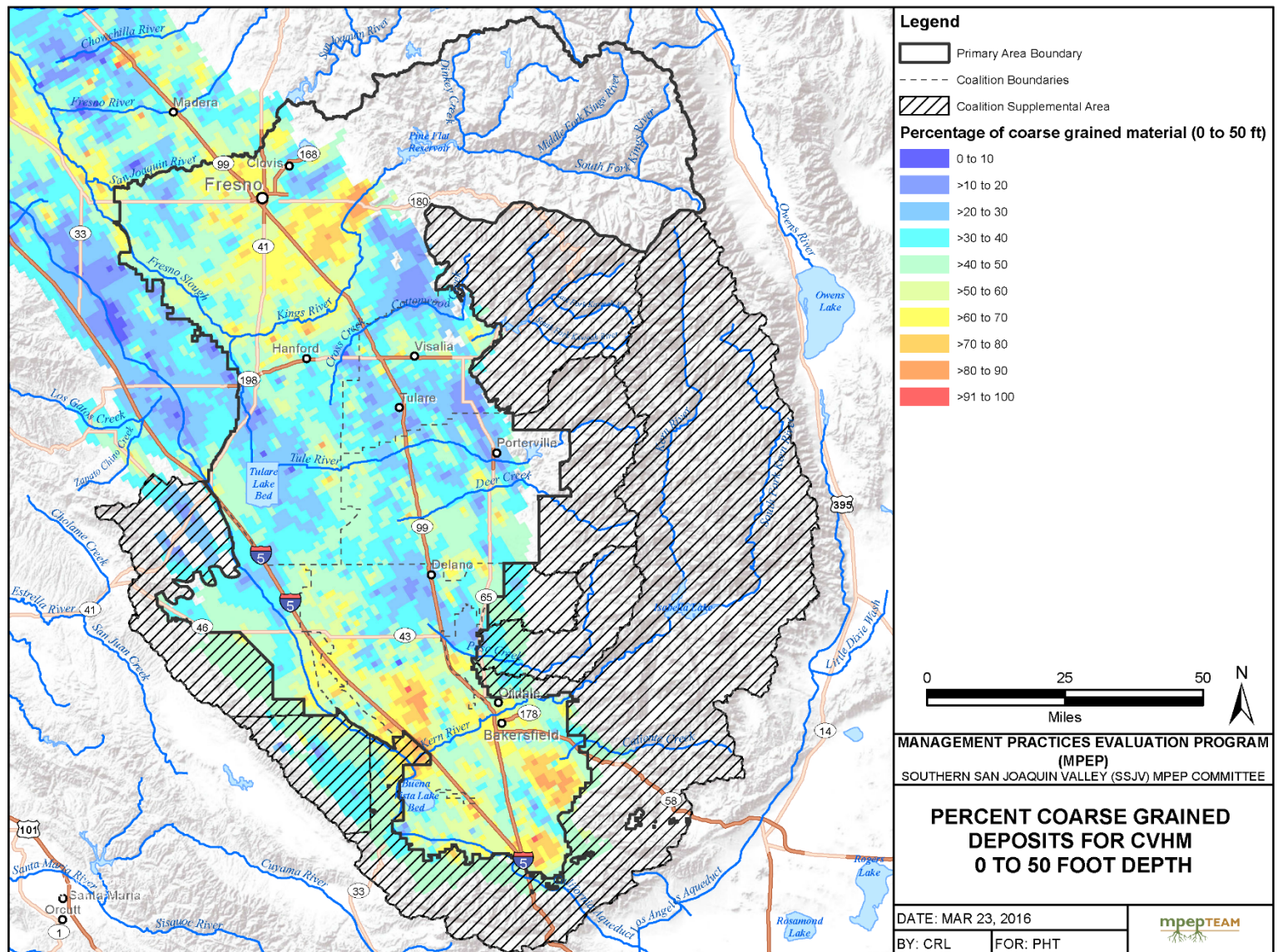


FIGURE 3-7. PERCENT COARSE GRAINED DEPOSITS FOR CENTRAL VALLEY HYDROLOGIC MODEL 0 TO 50 FOOT DEPTH

The CVHM (or CVHM2, when the revised version becomes available) provides a characterization of the vertical and horizontal distribution of hydraulic conductivity in the SSJV. It includes a three-dimensional sediment texture model (Faunt, 2009) and underlying aquifer flow parameters for unsaturated and saturated zones. The CVHM covers the entire primary SSJV MPEP area, and provides extensive and well-documented data and interpretation in readily-accessible geospatial formats.

- **Extent, Thickness, and Properties of Confining Clay.** The Corcoran Clay is the most laterally extensive confining unit in the San Joaquin Valley and is a dominant influence on hydrogeology. The presence or absence, thickness, and properties of the Corcoran Clay member and other clays have a major influence on how nitrate, salt, and other constituents at the land surface migrate within the groundwater system. The thickness and texture of the Corcoran Clay is an indicator of potentially constrained leakage into the underlying groundwater system. The CVHM will serve as a key resource for characteristics of the Corcoran Clay (Figures 3-6 and 3-7).

Other thin, discontinuous lenses of fine-grained sediments (clay, sandy clay, sandy silt, and silt) are also found within the SSJV above and below the Corcoran Clay. Where present, these clays may create locally perched water. Coalition GARs (e.g., Kings, Buena Vista, Westside, Kern) will provide characterization of other locally significant hydrogeologic conditions.

- **Depth to Water.** Depth to groundwater varies temporally and spatially and is based on hydrogeologic conditions, groundwater use, and recharge practices. The depth to water represents the distance from the land surface to the top of the water table (i.e., through the unsaturated zone), which affects travel times to groundwater. The SSJV MPEP assumes the simulated groundwater elevations and the land surface elevations in the CVHM model provide a reasonable preliminary estimate of the depth to water in the SSJV. Groundwater levels from other data sources such as the California Statewide Groundwater Elevation Monitoring (CASGEM) database, other online data sources, and coalitions (as available), will supplement data from the CVHM.

3.5.2.2 GROUNDWATER CONDITIONS

Groundwater quality data were gathered for the SSJV MPEP area from the California Department of Public Health, DWR, Geotracker, USGS, and Central Valley Water Board Dairy databases. Data from wells located in the upper zone of the aquifer system were selected, and water quality results from 2000-2016 were extracted for these wells. The readily available data include 1,326 wells and a total of 12,783 water quality tests for nitrate and total dissolved solids (TDS).

Within the 2000-2016 time period, average and maximum nitrate and TDS concentrations were calculated for each well. The results are shown on Figures 3-8 through 3-11. Results show that the highest nitrate levels occur in the central portion of the MPEP area. The lowest nitrate concentrations tend to occur in the northwestern part of the area, while the highest nitrate concentrations are generally in the Kaweah Sub-basin. Fewer data are available in the southern portion of the MPEP area compared to the north. Fewer TDS measurements are available compared to nitrate; however, the highest TDS concentrations are found in the western portion of the SSJV area. The very northern part of the MPEP area is characterized by lower TDS concentrations (generally below 1,000 milligrams per liter).

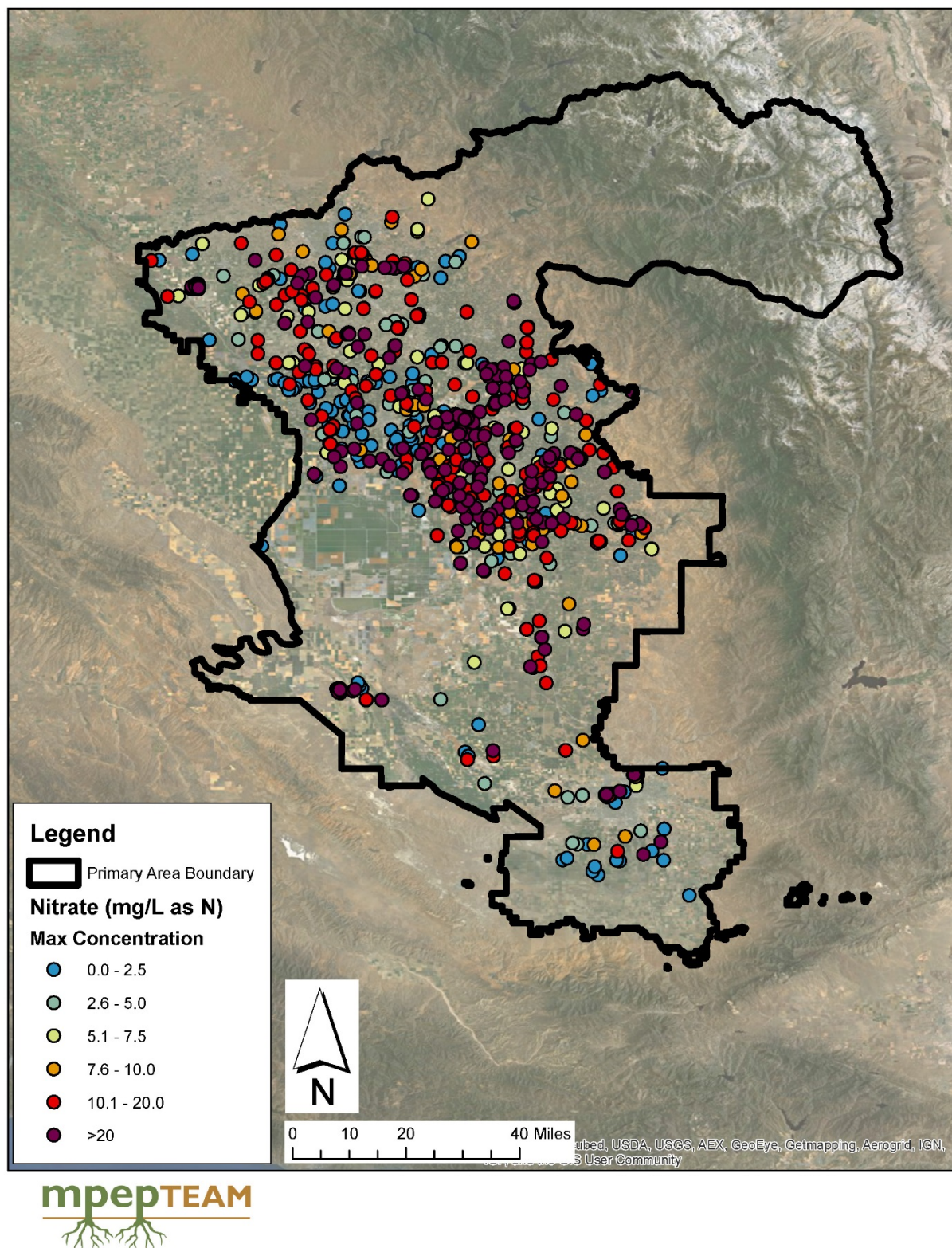


FIGURE 3-8. GROUNDWATER QUALITY UPPER ZONE WELLS CONCENTRATIONS SHOWN USING DATA FROM 2000-2016, SOUTH SAN JOAQUIN VALLEY MPEP

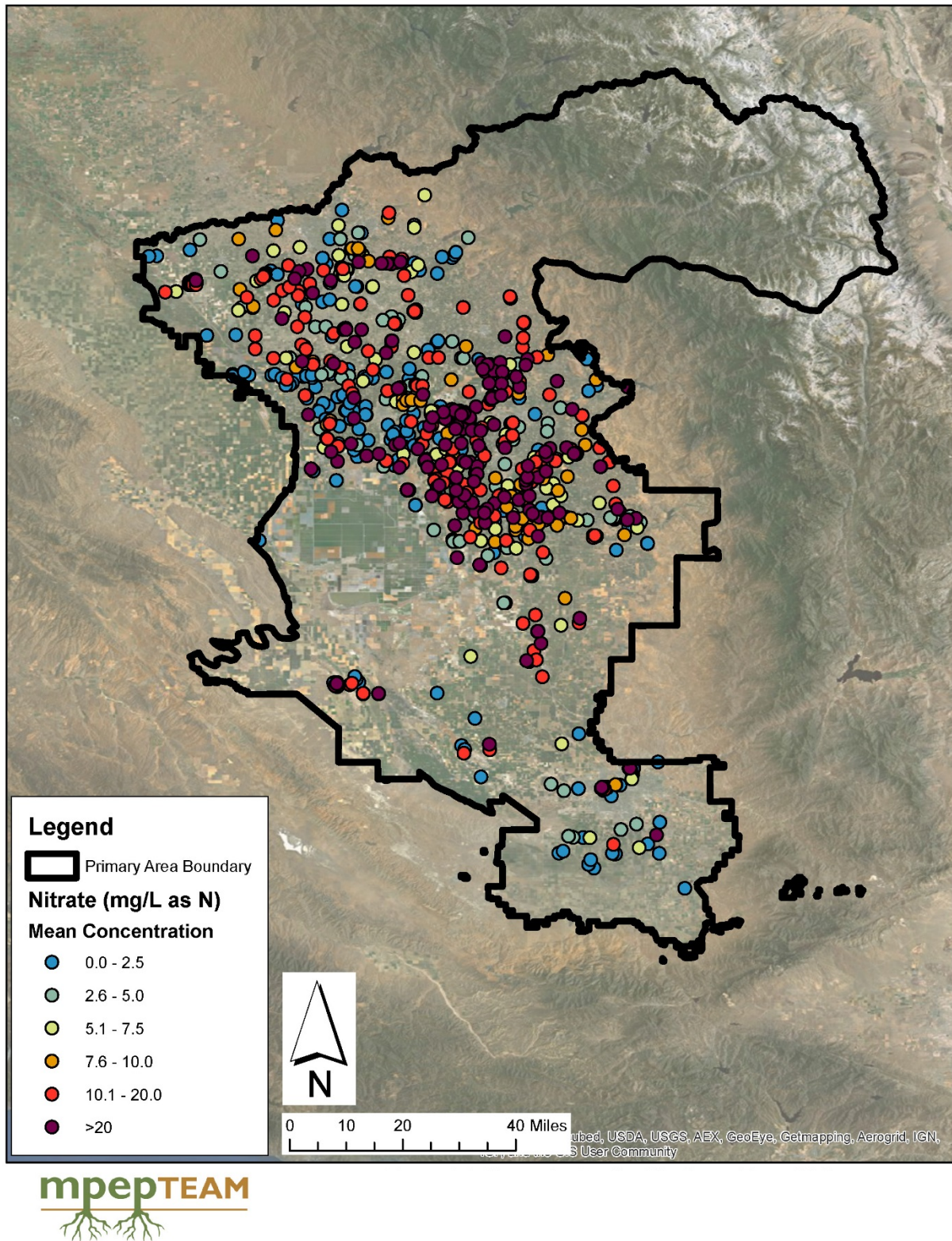


FIGURE 3-9. GROUNDWATER QUALITY UPPER ZONE WELLS CONCENTRATIONS SHOWN USING DATA FROM 2000-2016, SOUTH SAN JOAQUIN VALLEY MPEP

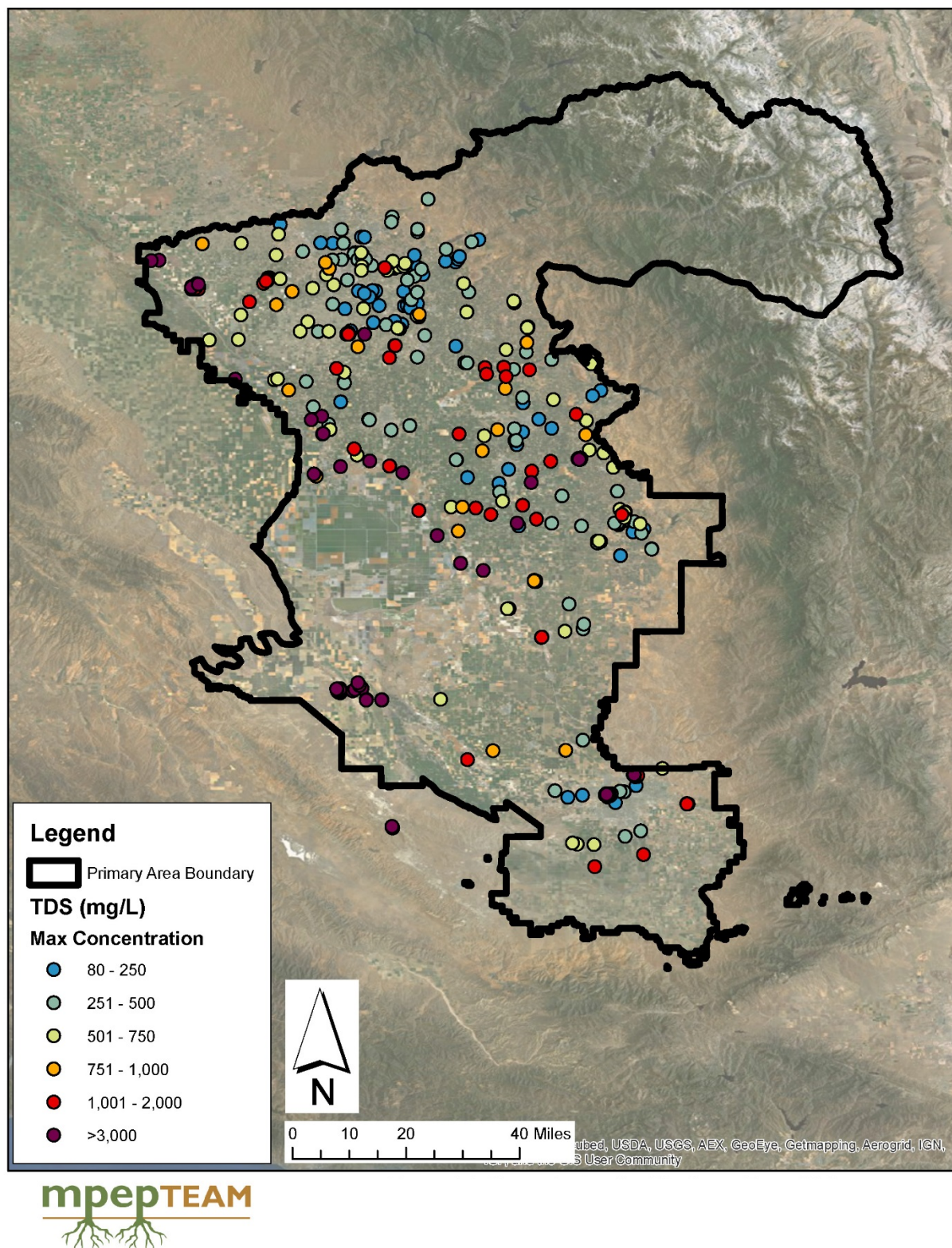


FIGURE 3-10. GROUNDWATER QUALITY UPPER ZONE WELLS CONCENTRATIONS SHOWN USING DATA FROM 2000-2016, SOUTH SAN JOAQUIN VALLEY MPEP

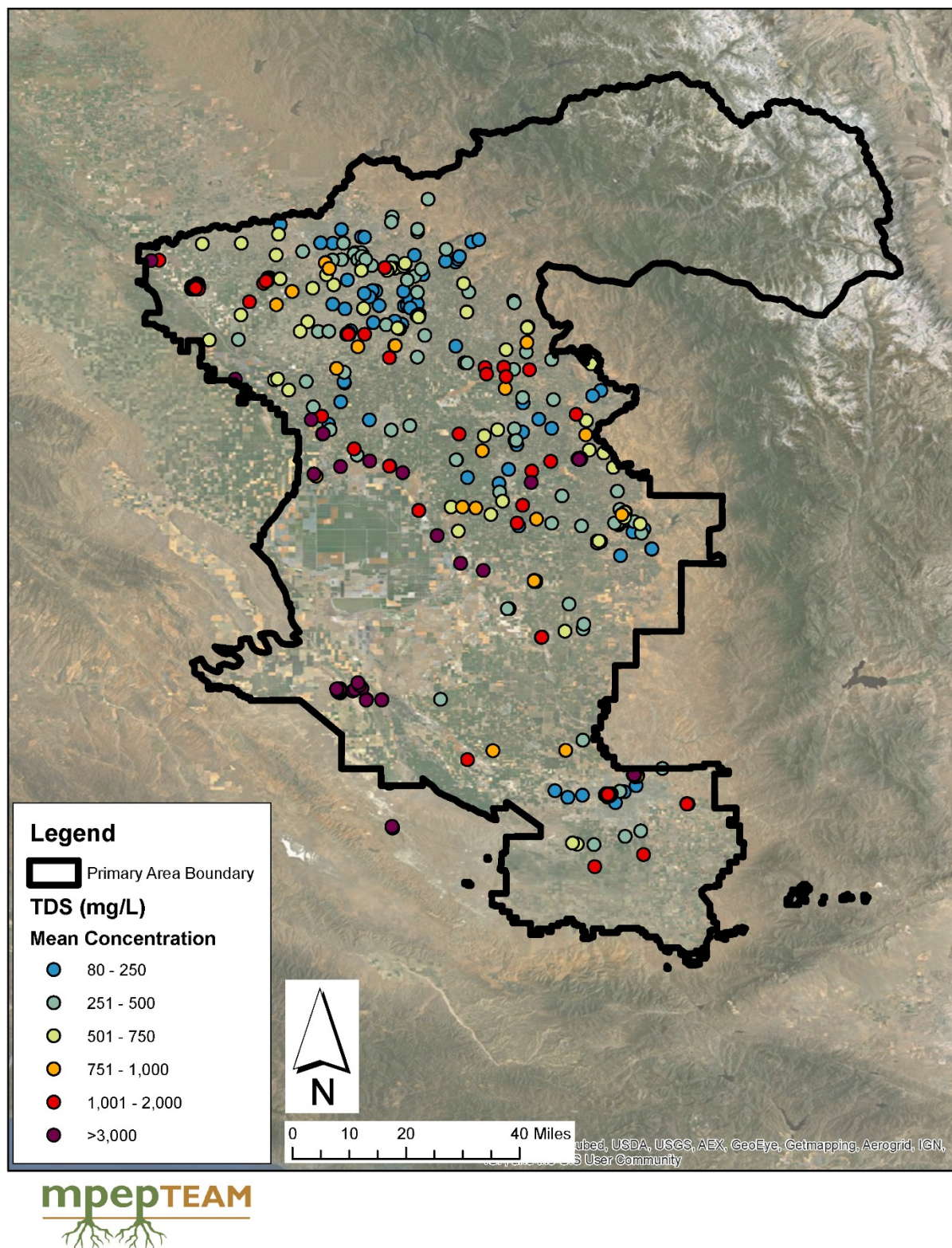


FIGURE 3-11. GROUNDWATER QUALITY UPPER ZONE WELLS CONCENTRATIONS SHOWN USING DATA FROM 2000-2016, SOUTH SAN JOAQUIN VALLEY MPEP

Required Outputs and Data Quality for Source Quantification and Anticipated Uses of Results

This component of the MPEP technical workflow contributes to meeting the following MRP requirements:

- *Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas.*
- *Develop an estimate of the effect of Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive officer or as a result of the recommendations by the expert panels by CDFA and the State Water Board, must be provided.*

Source Quantification results feed directly into the Initial Prioritization of Investigation (Section 3.7) and the Landscape-level Performance Assessment (Section 3.10). It can also provide more locally adapted recommendations (see Section 3.11) that are more useful to growers, and help focus management practice shifts into areas where they generate the greatest environmental benefit.

3.6 SOURCE QUANTIFICATION

The main goals of source quantification within this phase of the MPEP are the following:

1. Identify metrics, measurements, monitoring, and models that together can support robust and reliable estimates of the quantity of nitrate that moves below the root zone (hereafter called “nitrate loss”).
2. Apply robust modeling approaches to initially quantify ranges of nitrate loss across cropping systems and management approaches.
3. Contribute to identification and verification of protective management practices, especially in considering management in light of variable soil and climatic, and underlying geologic and groundwater conditions.

Such information will provide the basis for prioritization of field investigations, calibration of field and landscape models used to predict losses more generally across the landscape, and help to identify areas where specific practices yield the greatest environmental benefit. This information also will be used, as needed, in deliverables required for GQMPs.

It would be far too costly and time consuming to directly measure and monitor nitrate losses at a large number of locations, so it is preferable to leverage monitoring results by extrapolation through use of existing biophysical models. This approach follows from the fact that nitrate loss is governed by a large number of interacting factors (including soil properties, management, and weather) and processes that vary considerably over short time spans and spatial scales. Hence, it is critical to understand these interactions well enough to identify and focus on those factors that have the greatest influence on reducing nitrate losses. At the same time, it must be

recognized that managing those same factors and processes is crucial to productive and profitable crop production.

3.6.1 IDENTIFY PRIMARY NUTRIENT MANAGEMENT BMPs FOR EACH CROPPING SYSTEM GROUP

Nitrogen management is optimized in terms of yield, profit and environmental impact when the timing and amount of nitrogen available for uptake is precisely matched to crop demand in time and space throughout the growing season (Cassman et al., 2002). Such “just-in-time” N supply seeks to provide only that amount of nitrogen required by the crop at each phase of development, without deficiency or excess. The goal is to minimize the amount of surplus mineral nitrogen³ not immediately required by the crop because nitrogen losses from all pathways are directly proportional to the amount of N surplus. Indeed, a major advantage of irrigated agriculture is the capability to achieve substantially higher nitrogen fertilizer efficiency than in rain-fed crop production because irrigation provides the opportunity to coordinate nitrogen and water supply. For example, “fertigation” can provide several small doses of nitrogen with irrigation events timed to coincide with key growth stages rather than one or two large doses applied before and during early growth phases. Furthermore, irrigation renders the pattern of crop N demand more predictable by greatly reducing water stress as a limiting factor to crop growth and development.

Leveraging the advantages that irrigation brings to N management, however, depends on irrigation system design and management, and the efficiency and uniformity with which irrigation is applied. Investments to improve irrigation efficiency and uniformity can therefore help improve N fertilizer-use efficiency and reduce environmental N losses (Table 3-3, modified from Dzurella et al., 2012). Hence, in general, potential N efficiency is greatest with drip systems, followed by low-pressure sprinklers, which are more efficient and uniform than high-pressure sprinkler or surface irrigation systems. Performance of sprinkler and surface systems, however, can be high if a number of the management practices listed in Table 3-3 are implemented.

Modifications to cropping systems such as crop rotation and/or cover crops can improve N fertilizer efficiency or reduce environmental N losses (Table 3-3). For example, winter cover crops can use residual soil nitrate. Inclusion of deep-rooted crops, such as safflower and cotton, in annual crop rotations can capture nitrate that escapes below the root zone of shallower-rooted crops. Deep-rooted perennial crops can also play a nitrate-scavenging role in deeper soil layers. However, flexibility to modify a cropping system to reduce nitrate leaching is often limited by the lower economic value and profitability of the alternative crops or the additional costs associated with inclusion of a cover crop. Hence, cropping systems approaches are often less attractive to growers than investments in irrigation systems that can improve both irrigation and N efficiency, or in N fertilizer management that improves the synchrony of N supply and demand.

³ Mineral nitrogen refers to nitrogen in non-organic forms such as nitrate-N and ammonium-N, that are the forms directly taken up by plant roots and the forms lost via leaching, denitrification, and volatilization.

TABLE 3-3. MANAGEMENT PRACTICES DOCUMENTED TO IMPROVE NITROGEN FERTILIZER EFFICIENCY AND BARRIERS TO THEIR ADOPTION AS MODIFIED FROM DZURELLA ET AL. (2012)

Management Practice		Barriers to Adoption
Irrigation and Drainage Design and Operation		
Irrigation System Evaluation and Monitoring		
1	Conduct irrigation system performance evaluation	Operational cost, land tenure, training
2	Install and use flow meters or other measuring devices to track water volume applied to each field at each irrigation	Capital cost, operational cost, training
3	Conduct pump performance tests	Operational cost, training
Irrigation Scheduling		
4	Use weather-based irrigation scheduling	Operational cost, logistics, training, technology
5	Use plant-based irrigation scheduling	Operational cost, logistics, training
6	Use soil moisture content to guide irrigation timing and amount	Operational cost, logistics, training
7	Avoid heavy pre-plant or fallow irrigations for annual crops	Risk to yield or quality, logistics, training
Surface Gravity System Design and Operation		
8	Convert to surge irrigation	Capital cost, operational cost, logistics, training
9	Use high flow rates initially, then cut back to finish off the irrigation	Operational cost, logistics, training
10	Reduce irrigation run distances and decrease set times	Risk to yield or quality, capital cost, operational cost, land tenure, training
11	Increase flow uniformity among furrows (e.g. by compacting furrows)	Operational cost
12	Grade fields as uniformly as possible	Operational cost, training
13	Where high uniformity and efficiency are not possible, convert to drip, center pivot, or linear move systems	Capital cost, operational cost, land tenure, training
Sprinkler System Design and Operation		
14	Monitor flow and pressure variation throughout the system	Operational cost
15	Repair leaks and malfunctioning sprinklers; follow manufacturer recommended replacement intervals	Capital cost, operational cost, training
16	Operate sprinklers during the least windy periods, when possible	Logistics
17	Use offset lateral moves	Operational cost, logistics, technology

TABLE 3-3. MANAGEMENT PRACTICES DOCUMENTED TO IMPROVE NITROGEN FERTILIZER EFFICIENCY AND BARRIERS TO THEIR ADOPTION AS MODIFIED FROM DZURELLA ET AL. (2012)

Management Practice		Barriers to Adoption
18	Use flow-control nozzles when pressure variation is excessive	Capital cost, land tenure, training
Drip and Micro-sprinkler System Design and Operation		
19	Use appropriate lateral hose lengths to improve uniformity	Training, capital cost
20	Check for clogging; prevent or correct clogging	Operational cost, capital cost, training
Other Irrigation Infrastructure Improvements		
21	Installation of sub-surface drains in poorly drained soils ¹	Capital cost, technology
22	Backflow prevention	Capital cost, training
Crop Management		
Change Crops to Use Those with Smaller N Requirements and Greater N Efficiency		
23	Cover crops to recover residual soil nitrate and immobilize it in soil organic matter	Risk to yield or quality of cash crop, capital cost, operational cost, logistics, training, technology, increased irrigation requirements for the cash crop
24	Include deep-rooted or N-scavenger crop species in annual crop rotations	Risk to yield or quality, capital cost, operational cost, logistics
25	Include perennial crop in rotation, e.g. alfalfa or perennial grasses	Capital cost, logistics, land tenure
Nitrogen Fertilizer Management		
Improve Rate, Timing and Placement of N Fertilizers		
26	Adjust N-fertilizer rates based on soil nitrate testing	Operational cost, training
27	Adjust timing of N fertilization based on plant tissue analysis	Risk to yield or quality, operational cost, training, lack of robust relationships between tissue test and amount of N fertilizer required
28	Apply N fertilizer in small multiple doses, rather than one or two large doses, to meet crop demand during the growing season without deficiency or excess	Operational cost, training
29	Know N content of irrigation water and adjust fertilizer rates accordingly	Operational costs, logistics, training
30	Reduce total N-fertilizer rates by replacing low-uptake-efficiency N-fertilizer applications to soil with high-uptake-efficiency foliar-N applications	Operational costs, training, technology

TABLE 3-3. MANAGEMENT PRACTICES DOCUMENTED TO IMPROVE NITROGEN FERTILIZER EFFICIENCY AND BARRIERS TO THEIR ADOPTION AS MODIFIED FROM DZURELLA ET AL. (2012)

Management Practice		Barriers to Adoption
31	Vary N-application rates within large fields according to site-specific needs based on heterogeneity in soil N supply and/or crop growth	Operational costs, capital costs, training, technology
32	Use delayed injection procedure when fertigating in surface gravity systems	Operational costs, logistics, training
34	Develop an N budget that includes crop N harvest removal, supply of N from soil and other inputs to guide decisions on N-fertilizer rates and timing	Operational costs, training, technology
35	Use controlled release fertilizers, nitrification inhibitors, and urease inhibitors	Risk to yield quantity or quality, capital cost, training, technology, benefits depend on soil types and N-fertilizer management practices
Improve Rate, Timing, and Placement of Animal Manure and Organic Amendment Applications		
36	Apply appropriate rates of manure and compost, taking N mineralization characteristics of these organic N sources into account	Risk to yield quantity or quality, operational cost, logistics, training, technology
37	Incorporate solid manure immediately to decrease ammonia volatilization loss	Operational costs, training
38	Use delayed injection to improve application uniformity when applying liquid manure in surface-gravity irrigation systems	Operational cost, logistics, training, technology
39	Use quick-test methods to monitor dairy lagoon water N content immediately before and during application, and adjust application rate accordingly	Operational costs, training, technology
40	Calibrate solid manure and compost spreaders	Operational cost, logistics, training
Improve or Maintain Soil Health and Crop Vigor		
41	Holistic soil management to promote healthy soil conditions, including favorable levels of organic matter, infiltration rates, water holding capacity, soil life, vegetative cover, bulk density, etc.	Potential conflicts with timing or nature of commercial agricultural operations; time required to build soil health; influence varies among soil types
42	Maintain a vigorous crop to take up available N through timely planting and adequate fertility, irrigation, and weed and pest control.	Minimal barriers to adoption as it is consistent with profitable farming.

¹Presumably beneficial to N management primarily by promoting more uniform crop growth and N uptake across the field.

Regardless of irrigation system and cropping system, a number of improved management options have potential to increase N fertilizer efficiency and reduce the amount of residual soil nitrate at risk of leaching. Numerous practices are identified in Table 3-3. Along with more technical, specific management of water, crops, and fertilizer (items 1 through 40), growers can also manage their overall

system for better “soil health” (item 41, i.e., having adequate organic matter or soil carbon), which tends to increase the soil’s capacity to retain water and nutrients for subsequent crop uptake. For all such practices, the goal is to better match N supply with crop demand in both time and space. Selection of the most appropriate and cost-effective best management practice (BMP) depends on crop, irrigation system, water quality, and soil type, *which means there is no universal set of BMPs relevant for all situations*. Instead, growers must create their own package of BMPs that best suits conditions on their farms. Consultations with UCCE faculty and crop consultants (e.g., CCAs) can help identify and fine-tune these practices. To an extent, modeling tools employed for quantification in the MPEP have excellent potential to provide more systematic assessment (mapping) of where suites of practices provide the greatest benefit. This approach to adapting recommendations to the landscape is a novel, yet very promising approach that appears to be unique to this MPEP.

Accurate estimates of N supply from all sources, in addition to fertilizer, provide a powerful tool for supporting implementation of BMPs for fertilizer management. The cost-effective quantity of N fertilizer for a given field is highly sensitive to the amount of N inputs from residual soil nitrate, application of manure or compost within the past (at least) 2 years, nitrate in irrigation water, and use of legume cover crops. The optimal fertilizer rate is also influenced by crop uptake, which is generally correlated with crop yield. Therefore, BMPs for N management should involve the growers’ use of N input and output records from each production block to estimate the N balance (see next section).

3.6.2 QUANTIFY N BALANCE AND N SURPLUS ACROSS CROPPING SYSTEMS AND BMPs

The N balance/N surplus approach provides a strong conceptual foundation for quantifying the amount of nitrogen at risk of loss as nitrate. The overarching goal is to minimize the size of the N surplus under the assumption that the potential for N losses to the environment via all pathways is proportional to the magnitude of N surplus—defined as the difference between N inputs from all sources and N removal in harvested crop biomass. For example, recent publications have found that the risk of N losses is well correlated with the amount of N surplus and that the relationship is robust for nitrate leaching and denitrification (Dalgaard et al., 2012; Van Groenigen, 2010; Zhou and Butterbach-Bahl, 2014).

3.6.2.1 NITROGEN BALANCE

Nitrogen balances are estimated at the field level and require information about all significant N-input and N-removal components. Nitrogen inputs include chemical fertilizer, manures and composts, biological N fixation by legume crops (e.g., beans, alfalfa, clovers, and other legume cover crops), nitrate in applied irrigation water, and atmospheric N deposition. Nitrogen removal is the product of yield and the N concentration of that yield in terms of harvested grain, fruit, nuts, forage, leafy vegetables and harvested crop residues. The components of a typical field-level N balance are presented in Figure 3-12. It is generally straightforward to construct an N balance by using measurements or estimates of N quantities for the contributing components. For example, most growers keep records of the amount of fertilizers they apply, and the N content of N fertilizer products is well known. Likewise, N content of applied manures and compost is often measured by the provider, or can be estimated based on standard values for the type of manure or compost, including N availability. Estimating input from legume biological N fixation is more difficult, but estimates are available based on the legume species

grown. Most growers have their irrigation water tested at regular intervals to determine salinity levels, and nitrate concentration is typically included with these analyses. Finally, estimates of atmospheric deposition within the SSJV can be obtained from the National Atmospheric Deposition Program/National Trends Network,⁴ which operates monitoring stations and publishes gridded maps of atmospheric deposition rates across the United States.

On the N-removal side of the ledger, growers know the yields obtained from their fields, and standard values for the N concentrations of each commodity can be used to calculate N removal. There is a moderate degree of variation, however, in N concentrations of harvested materials due to interactions between N management and yields that cause a “dilution effect.” In years or on fields with higher than average yields, the N concentration in harvested materials tends to be lower than standard values, due to N dilution within the greater dry matter production. The opposite is true in low-yield years. When it is necessary to tighten the estimated N balance, direct measurement of N concentration in harvested materials can improve accuracy. Likewise, given the importance of N removal to the N balance estimates, focused surveys of N concentrations in harvested materials for the major crops in the SSJV might improve understanding of average concentrations, the magnitude of variation, and the reasons for it. This knowledge can in turn be applied to improve the accuracy in estimating N removal.

(Note to readers: The following three sentences refer to sampling or surveys under the auspices of research, and are not intended to imply additional measurement to be made routinely by growers in most or all fields.) When it is necessary to tighten the estimated N balance, direct measurement of N concentration in harvested materials can improve accuracy. Likewise, given the importance of N removal to the N balance estimates, focused surveys of N concentrations in harvested materials for the major crops in the SSJV might improve understanding of average concentrations, the magnitude of variation, and the reasons for it. This knowledge could in turn be applied to improve the accuracy in estimating N removal.

⁴ <http://nadp.sws.uiuc.edu/>

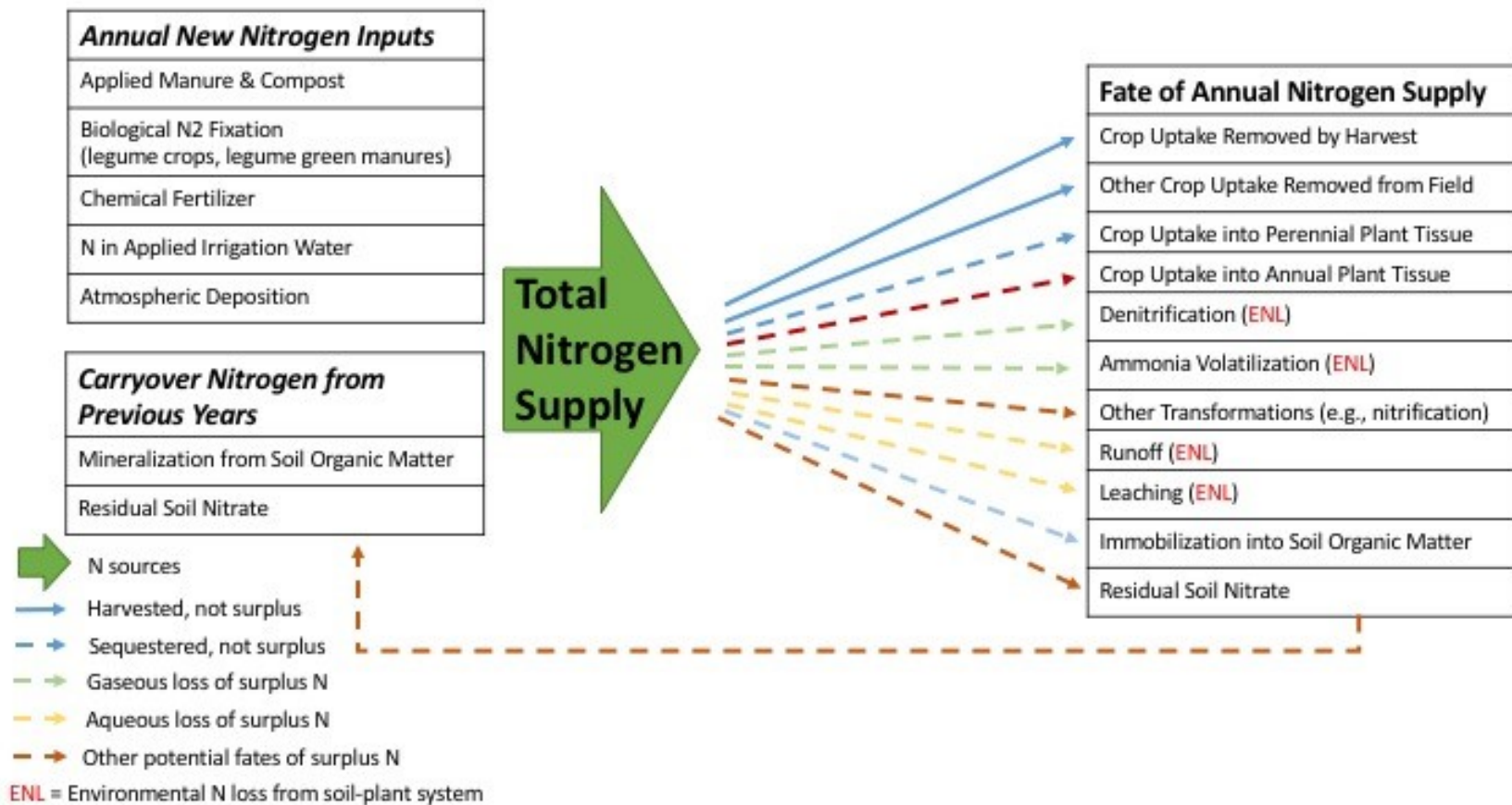


FIGURE 3-12. IDENTIFICATION OF MAJOR N SOURCES AND SINKS, AND PATHWAYS FOR LOSS OR STORAGE OF N SURPLUS

3.6.2.2 NITROGEN SURPLUS

Nitrogen surplus is not the same as N loss. Some of the N surplus is retained in soil organic matter or in standing biomass of perennial crops (trunks, branches, and roots), or held in the soil to the next season as available mineral nitrogen. In general, however, soil organic matter content reaches an equilibrium level in fields that have been cropped for a period of time under a consistent cropping system.

Therefore, unless there is a significant change, such as the crops grown, inclusion of cover crops, or changes in tillage method, it is likely that organic matter levels are relatively constant and there would be little net retention of N surplus in organic matter. If there is evidence of soil organic matter accumulation (e.g., direct measurements documenting changes in soil organic matter content), then the N surplus calculated as the difference between inputs and removal is reduced by the amount of nitrogen in the accumulating organic matter. In fields with declining levels of soil organic matter, the nitrogen contained in the lost organic matter adds to the N surplus. Similarly, while there is little net biomass accumulation in mature orchards, young orchards accumulate a small amount of nitrogen each year, and this amount is subtracted from the N surplus. Hence, the N surplus corrected for an increase (or decrease) in soil organic matter and for N accumulation in perennial crop biomass, is called the net N surplus, and it represents the quantity of nitrogen that may be lost from, or stored in, the root zone.

The net N surplus can be lost via one of four environmental pathways: ammonia volatilization, denitrification, downward leaching, and runoff. Because it is costly to measure each of these N-loss pathways, and the rate of loss varies considerably over short time periods and distances, simulation models can be used to estimate these losses by accounting for the processes and factors governing the rates of loss. Accurate estimation of the net N surplus is a prerequisite for robust estimation of losses by each pathway. Therefore, robust estimates of the net N surplus, based on good quality data for the component N inputs and removal amounts as described herein, can be used to calibrate and assess the performance of the simulation models used in the MPEP to estimate field- and landscape-level nitrate leaching.

3.6.2.3 NITRATE LEACHING

For nitrate leaching, a key factor is the concentration of nitrate in the soil's root zone. Hence, robust estimates of nitrate leaching depend on how much of the net N surplus ends up as root-zone nitrate. One complicating factor, however, is that nitrate in the root zone is not uniformly distributed. Distribution is affected by patterns of water application from irrigation systems (drip, surface, sprinkler), the type of N source (fertilizer, manure, compost), method of fertilizer application (soil incorporated, injected, surface applied, foliar spray, water-run in surface irrigation, or through drip or sprinkler irrigation), and patterns of depletion through denitrification, uptake, immobilization, and leaching. The interaction of spatial distribution and type of irrigation system can have a large influence on the amount of nitrate loss via leaching. Nitrate spatial distribution, and the relationship to the irrigation system, therefore need to be considered. A potentially high priority for research led by MPEP partners is to

better understand how management affects the distribution of nitrate in the soil profile and how this distribution affects rates of nitrate leaching (Sections 3.7 and 3.8).⁵

3.6.2.4 USING THE N BALANCE/N SURPLUS APPROACH

The N balance/N surplus approach also provides a strong foundation for evaluation of management practices that decrease N losses. It is relatively straightforward and efficient to obtain the data required for a robust estimate of the net N surplus. This parameter will be used as the primary criterion to determine the effectiveness of improved and innovative management systems to reduce nitrate losses. Other metrics and formulations, such as A/R (applied N/N removed from the field in harvested material, or sequestered in perennial biomass, a metric mandated in the General Order) are better adapted when collecting comprehensive (all management blocks) data, due to their relative simplicity. Therefore, A/R and other metrics will be studied in parallel with N surplus to provide the more detailed picture of N fate, as intended and required in the MPEP.

It should be noted that the components of the N-surplus calculation, and the concept of balancing inputs and outputs, align well with Nitrogen Summary Report, which is also required by the General Order. The manner in which the balance is calculated for the MPEP differs from how it is calculated for the Nitrogen Summary Report; however, this does not create a conflict because the data source and end use of the balance also differs between the Nitrogen Summary Report and the MPEP. Nitrogen surplus is preferred in the MPEP as an indicator of N balance and potential risk not only at the field level, but also at the landscape level. One reason it is used widely for these purposes is that it is measured in familiar units (pound per acre), facilitating interpretation. Furthermore, summarizing N balance data in more than one way can enhance understanding of N balances and their relationship to the fate of applied nitrogen.

In summary, the MPEP will use the N balance/N surplus approach as the central organizing framework to guide efforts to reduce landscape-level N loss through management. At the same time, the MPEP will provide even better estimates of nitrate loss by using simulation models at the field and landscape level. Together, these results, along with trends in A/R, are the MPEP criteria for evaluating the efficacy of improved management practices and systems designed to reduce nitrate losses. Of course, each of these quantifications needs to be checked against more definitive data obtained from field studies and sampling, wherever these are available.

As noted previously, use of the N balance/N surplus approach relies on robust estimates of N inputs and outputs (Figure 3-12). Characterizing the current status of these balances for all major crops and cropping systems is the first step towards implementing this approach. Initially, the MPEP will rely on existing data sources to construct rough balances, followed by efforts to fill in missing elements and improve overall data quality. For example, approximations can be obtained from documentation of typical fertilization rates (Rosenstock et al., 2013; Dzurella and Pettygrove, 2014), or information from

⁵ While it is important to prioritize, target, and reasonably minimize expenditure on research in the MPEP, it will nevertheless be necessary to do a fair bit to ensure that practices' performance is well understood so that growers and analysts can proceed with confidence, and persuade agencies relative to statements about the MPEP's influence on future N loading. The repeated references to research are made in this context.

CCAs and growers (e.g., Nitrogen Summary Report data). Additional data will likely be needed to fine-tune estimates of key N balance components; and these can be targeted in subsequent survey and potential field studies. To that end, improved prediction of crop N removal in relation to spatial and temporal variability in the N concentration of harvested crop materials is an important component of an accurate N balance. The N balance in turn helps estimate N fertilizer required to meet N demand while also considering other sources of N input. Likewise, accurately predicting the fate of the net N surplus (how it is allocated among alternative soil storage and environmental N loss pathways) is essential for accurate estimation of residual soil nitrate in the root zone that may be at risk of leaching. Indeed, the net N surplus that ends up as residual nitrate strongly influences estimates of nitrate movement from the root zone.

3.6.3 BENCHMARK EXISTING LEVEL OF BMP ADOPTION

Another important MPEP objective is to provide a quantitative framework to predict how adoption of BMPs can reduce nitrate losses to groundwater (Section 3.10). Achieving this objective will require characterizing the current N balances and net N surpluses for the most vulnerable regions, crops, and cropping systems (Section 3.6.2), as well as benchmarking the current degree of adoption of BMPs across the MPEP area. These benchmarks provide a baseline against which increases in BMP adoption levels can be evaluated for their impact on reducing nitrate losses using models (Section 3.10) and targeted field studies (Section 3.8).

3.7 INITIAL PRIORITIZATION OF INVESTIGATIONS

Achieving the MPEP objectives requires prioritizing field studies and other investigations. One challenge is that the magnitude of N losses and impact of adoption of BMPs depends on many factors, including landscape position, soil type, cropping system, and the individual crop in the system. The number of permutations of these different factors within the SSJV is enormous, and far too large to allow monitoring coverage or research of all existing combinations. However, meeting the overall goal of the General Order (Section 1.1) will require that results from strategic groundwater and vadose zone sampling be obtained and evaluated. In some cases, focused field studies and survey sampling will be needed. A key question is how best to select the most appropriate locations, crops, and management practices to ensure that these relatively costly efforts have greatest impact in contributing to the MPEP goals.

Based on initial discussions with coalition partners, review of coalition GARs, and discussions within the MPEP Team, the following criteria are proposed as the basis for selection of in-depth sampling and field studies:

1. Crops that represent the largest land area and economic value.
2. Crops and cropping systems with the largest N surplus and/or largest depth of leaching water applied.
3. Crops and cropping systems preferentially grown on coarse soils (e.g. sweet potatoes).

4. Crops and cropping systems in areas with shallow depth to groundwater (i.e., hydrogeologic sensitivity).
5. Regions of the MPEP area classified as disadvantaged communities (i.e., proximity to public groundwater supply wells).

Initial modeling results, along with assessments of soil, vadose zone, and groundwater properties, as well as crop area distribution, will provide a basis for prioritizing effort relative to these criteria. Magnitudes of crop production area and value of the major commodities (presented in Table 3-1 in, Section 3.5.1.1) will inform decisions about crop selection for more detailed study and data collection. Included among the most important crops in terms of area and value are fruit and nut crops (almond, citrus, pistachios), field crops (cotton, alfalfa, silage corn [exclusive of dairy], wheat), and vegetable crops. While this list is large, some of these crops tend to be located in less vulnerable areas (deep groundwater, fine-textured soils) or tend to have relatively low N fertilizer requirements (grapes, wheat, alfalfa) and so may not be high-priority targets. These criteria will be applied in consultation with stakeholders (member coalitions, Central Valley Water Board, grower organizations, and UCCE) to develop a detailed set of priorities during the first phase of MPEP implementation.

In addition, if additional constituents need to be addressed by growers, such as those that may be required pursuant to GQMPs, the MPEP will be updated to serve the same functions for those constituents in consultation with the affected coalition and the Central Valley Water Board. This may include updating the schedule (Section 3.1) and the prioritization of investigations.

3.8 FOCUSED FIELD STUDIES

While the modeling effort will be led by the MPEP Team with support from a broad range of collaborators, field (and sometimes laboratory and greenhouse) studies, when necessary, generally will be led by public- sector collaborators with funding from programs like the CDFA

Required Outputs and Data Quality for Focused Field Studies, and Anticipated Uses of Results

This component of the MPEP technical workflow contributes to meeting the following MRP requirements:

- *Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas.*
- *Develop an estimate of the effect of Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive officer or as a result of the recommendations by the expert panels by CDFA and the State Water Board, must be provided.*

Results from Focused Field Studies will feed directly into Outreach (see Sections 2.4 and 3.11) and the Landscape-level Performance Assessment (see Section 3.10).

FREP and commodity organizations. However, contributions from such studies will provide the greatest benefit if the MPEP Team consults actively with investigators in identifying investigation priorities (Section 3.7), planning and design of studies, promoting adequate funding and workable schedules, interpreting results relative to performance goals, and focusing and developing outreach activities that explain results to grower advisors and to growers themselves.

Collaborating researchers are generally the best suited to design field investigations and surveys that they will conduct, therefore, no research design template is included in this Workplan. However, some examples of the general types of studies that will be helpful in completing the MPEP serve to illustrate the range of work that is anticipated. In all cases, the goal will be to relate specific management practices and cropping systems to the fate of applied nitrogen, or to other constituents of concern if required by GQMPs. In addition, existing literature will be exhausted first, and fieldwork (of which only a limited amount can be funded) will be directed at priority questions that cannot be adequately resolved with existing knowledge alone.

A few examples of investigations in the broad categories of surveys, sampling, and calibration follow.

3.8.1 SURVEYS

Much can be learned by benchmarking current grower management practices and the responses of the crops and soils subject to that management. However, due to their broad reach, survey results can often lack detail. Nevertheless, they can be a useful tool. Specific examples of survey-type studies include the following:

- Studies of management practice and production data from Farm Evaluations and Nitrogen Summary Reports, as supported and sanctioned by member coalitions, as well as similar data from packers who may gather such data from growers with whom they work. If these data are of sufficient quality, they could provide extremely powerful information about grower practices. They can also be summarized and shared with growers in formats that put field-specific management and outcomes into the context of what occurs in other, similar operations.
- Collaborative studies of crop production with grower, canner, packer, and commodity groups including the following:
 - Yield-level relationships to tissue N concentrations or leaf color, which are often specific to cultivar and stage of growth. In some cases, refinements of tissue concentration-production relationships, and development of convenient evaluation tools, can help growers fine-tune N applications. Like other tools, this approach is not effective for all crops and settings, but can be helpful where yield/tissue relationships are strongest.
 - In perennial tree crops, field studies and modeling that better define active root-zone soil volume for estimating residual soil nitrate, which is influenced by crop, soil-type, and irrigation system. How much of the total soil volume should be considered when

sampling soil to estimate residual nitrate, which is a sensitive parameter for estimating N fertilizer requirements?

- N content of harvested materials to improve estimates of N removal. As discussed previously, N-removal estimates are part of N-balance-based management planning. Where estimates can be significantly improved by focused surveys and incorporated into convenient tools, this could contribute to improved N-application decisions.
- Studies assessing the grower acceptability, production impact, and environmental performance of specific suites of practices aimed at maximizing the proportion of applied N used by the crop, and reasonably minimizing the mass of N leached below the root zone. Performance assessment in these studies is discussed in more detail in the next section.

3.8.2 SAMPLING

Sampling of plants, soils, soil water, and (occasionally) shallow groundwater can be used in focused field investigations to resolve specific questions about the fate of applied N, and how the risk of nitrate leaching can be reduced by management. The following are types of sampling and field investigations that would be helpful to the MPEP Team:

- Vadose-zone modeling can be used to predict the eventual influence of management practices on groundwater quality. Because groundwater is relatively deep across most of the MPEP area, it takes a relatively long time for the effects of management practices on overlying irrigated lands to manifest in that deeper groundwater. It is therefore difficult or impossible to discern the influence of contemporary management of irrigated lands on groundwater in less than decadal periods by direct measurement of groundwater properties. For this reason, it will be necessary to measure more immediate responses in the root zone to understand the fate of applied nitrogen, and to predict the eventual influence of management practices on groundwater quality. If this approach is to be used, it will be helpful to demonstrate whether root-zone conditions can be related to site-specific groundwater quality concentrations near the water table. Vadose zone modeling provides one way to do this because the models can incorporate long timeframes. Another way is to investigate the relationship between crop management leaching at locations where the travel times from root zone to groundwater are as brief as possible. Thus, the relationship of root zone observations to shallow groundwater quality response will be studied at a few locations carefully selected for their very short travel times from root zone to groundwater. These sites will be selected in land units with: (a) relatively high vertical hydraulic conductivity through the soil, and (b) relatively shallow depth to groundwater.
- Focused field (or in some instances, lab, greenhouse, or modeling) investigations can confirm the effectiveness of existing practices or test promising new technologies and novel approaches. This would be particularly applicable where specific management practices are identified as potentially protective (i.e., resulting in a significant reduction in amount of applied N leaching to

groundwater, likely by routing it more efficiently to crop uptake) in a high-priority setting, and where existing field results provide inadequate information to support and/or justify outreach and implementation. Such studies will likely cover a representative range of field conditions and use a variety of monitoring designs. Experimental sampling combinations for determining N fate and transport are outlined in Figure 3-13 (comparing N balance, tensiometers, lysimeters, etc.). The methods differ and vary in degree of difficulty, but can be used together to nourish a broader understanding of what occurs on the landscape. In the figure, methods generally increase in complexity, cost, and accuracy from left to right. The more costly approaches can be used to calibrate and evaluate the performance of the less costly approaches. Methods to the left can be deployed more widely due to their lower cost. The “N balance” method is essentially what is used in the Nitrogen Summary Report and N-surplus calculations, and so is very widely deployed.

Parameter ^a	Approach for Determining N Fate and Transport			
	N Balance	Soil Samples	Darcy's Law, Pore Water Sampling	Leachate Capture
Applied N	Measured			
Gaseous losses	Estimated			
Uptake	^c			
Water potential differential ^b				
Hydraulic conductivity				
Soil bulk density		^d		
Soil moisture ^b				
Soil nitrate concentration				
Leachate nitrate concentration ^b				
Leachate volume ^b				
Leaching nitrate flux		Calculated		

^a Some parameters are exceptionally variable in space and time, and are therefore uncertain.

^b Measured with various moisture monitoring and soil water sampling equipment.

^c This parameter is usually based on measurements of yield, from which uptake is calculated.

^d This parameter can be measured, but more often is estimated based on measurements in the same or similar soils.

FIGURE 3-13. OPTIONS FOR MEASURING (GREEN), ESTIMATING (BLUE), AND CALCULATING (ORANGE) LEACHING LOSSES FROM ROOT ZONES. EACH COLUMN IS A COMBINATION OF MEASUREMENTS, ESTIMATES, AND CALCULATIONS BY WHICH THE N LEACHING FLUX IS DETERMINED. METHODS GENERALLY INCREASE IN COMPLEXITY, COST, AND ACCURACY FROM LEFT TO RIGHT.

Specific approaches will be determined based on the specific goals of each study, and will be principally determined by technical partners with deep knowledge, expertise, and (physical and institutional) infrastructure to design, implement, and perform such studies. Results from such studies will feed into: outreach and implementation; calibration of transport modeling; and evaluation of performance following implementation to demonstrate MPEP success.

- When questions pertain mainly to grower needs, behavior, and outcomes, information can be requested from growers, and then analyzed to complete this work. Coalition relationships with growers are crucial to the success of this work. To the extent that the MPEP and associated activities continue to be perceived as credible and worthwhile, grower participation should be strong. Such studies are a means to examine and understand operations in greater depth than may be apparent from the cursory but spatially comprehensive (every field) results of the Farm Evaluation and Nitrogen Summary Report. In this way, survey studies can complement other facets of the Order by providing a context in which practice and performance data collected by coalitions can be interpreted.

3.8.3 MODEL CALIBRATION AND PERFORMANCE EVALUATION

Biophysical models employed in the MPEP do not rely on monitoring data to function. The component models were indeed developed this way, but being physically based, respond with some accuracy to the passage of time, in the management, climatic, and soil environment described by the model inputs. However, to identify adjustments needed to ensure that the output provides an acceptable representation of reality, comparison with field observations is helpful, and in some cases essential to adapt sub-models to conditions or crop genotypes for which they may not have been calibrated. Existing data, such as results of past field studies, and site-specific measurements of parameters like evapotranspiration and crop yield, can be used to evaluate the performance of key components of the models. Where existing data are lacking for a high-priority setting, the following can provide the needed information:

- Field study results are an excellent way to calibrate and evaluate the performance of fate and transport models.
- Collaboration with grower, packer, and commodity groups can provide management and crop yield information in an efficient manner to improve modeling performance.
- Where water-balance data are being collected for other purposes (this is happening in the context of the Sustainable Groundwater Management Act processes), these data can be leveraged to help calibrate the crop water relations components of models.
- In all cases, different, more detailed or single-purpose models (such as Hydrus for soil water movement) can be run with similar inputs to check for congruence with the landscape-level model results.

3.9 A MULTI-PRONGED APPROACH TO ASSESSING THE INFLUENCE OF IRRIGATED LANDS ON GROUNDWATER QUALITY

This section describes a multi-pronged approach (i.e., groundwater monitoring and modeling) to assessing the influence of irrigated lands on groundwater quality. The section begins with a brief summary of the goals and objectives of the MPEP (as defined by the General Order), followed by a description of groundwater monitoring as an assessment tool, a description of the Workplan approach and rationale, and a method to identify areas for groundwater monitoring.

3.9.1 GOALS AND OBJECTIVES OF THE MPEP PERTAINING TO GROUNDWATER

In addition to the provisions cited in Section 1, the General Order also states the following preference for inclusion of groundwater monitoring:

Sufficient groundwater monitoring data should be collected or available to confirm or validate the conclusions regarding the effect of the evaluated practices on groundwater quality.

(See General Order page MRP-20, Section IV.D.)

In the following, the General Order also specifies monitoring of first-encountered groundwater as the only acceptable type of groundwater monitoring for the MPEP:

Any groundwater quality monitoring that is part of the workplan must be of first encountered groundwater.

See General Order page MRP-20, Section IV.D.

In addition, the Central Valley Water Board's Groundwater Monitoring Advisory Workgroup (GMAW), in conjunction with Central Valley Water Board staff, identified several questions to be answered by the groundwater monitoring conducted for the LTILRP⁶. The GMAW questions are listed in Table 3-4. The General Order states that the MPEP must be designed to answer GMAW questions 2, 5, 6, and 7; trend monitoring has been developed to answer GMAW questions 1 and 4.⁷

The GMAW questions illustrate the complexity of the issues surrounding non-point source agricultural losses to groundwater, including different geographic scales ranging from local (i.e., field scale) to regional, and different temporal scales ranging from short-term (i.e., possibly necessitating within-season tracking of certain processes) to decadal. Each of the questions implicitly necessitates consideration of geographic and/or temporal scales in devising a comprehensive program that

⁶ Groundwater chemical concentrations observed near the water table in first-encountered groundwater and in deeper aquifer zones (e.g., zones tapped by domestic wells, municipal, and agricultural supply wells) will play a critical role in the overall LTILRP. The MPEP Team's understanding is that the General Order's choice of words does not intend to suggest that these questions are to be answered solely by groundwater monitoring. For example, groundwater monitoring will contribute little if any to the identification and quantification of properties listed in GMAW question 5 or to the transport mechanisms alluded to in GMAW question 6. Other GMAW questions explicitly refer to the investigation of non-groundwater quantities (e.g., vadose zone, management practices, site conditions). Overall, it appears that each of the GMAW questions will require some degree of effort in addition to groundwater monitoring.

⁷ GMAW question 3 is not directly associated with either the MPEP or the GQTMP.

addresses the more site-specific nature of the MPEP and the more regional nature of the Groundwater Quality Trend Monitoring Program (GQTMP). Important considerations include the selection of tools and methods and the scoping of specific investigations within the MPEP. Both the MPEP and the GQTMP are specified in the General Order and there is a natural linkage between the two. Table 3-4 shows the seven GMAW questions and the associated programs that the General Order identifies to answer these questions.

Importantly, groundwater quality in the Central Valley is affected by more than just agricultural operations regulated under the LTILRP. Therefore, for evaluation of regional and long-term agricultural impacts, baseline and future groundwater quality data must be interpreted in the context of all pertinent contributing factors. These factors include precipitation patterns (e.g., successions of wet years, dry years, etc.); expansion or contraction of agriculture as a whole; changes in agricultural land use (e.g., annual crop rotations, changing from annual to perennial crops, forage crops for local dairies); surface water inflow into the Tulare Lake Basin; land management affecting natural recharge; and artificial recharge projects. Quantitative assessment of these factors will likely require groundwater modeling.

TABLE 3-4. GROUNDWATER MONITORING ADVISORY WORKGROUP (GMAW) QUESTIONS IDENTIFIED IN THE GENERAL ORDER

GMAW Question ¹		Program Specified in General Order ²
1	What are irrigated agriculture's impacts to the beneficial uses of groundwater and where has groundwater been degraded or polluted by irrigated agricultural operations (horizontal and vertical extent)?	GQTMP
2	Which irrigated agricultural management practices are protective of groundwater quality and to what extent is that determination affected by site conditions (e.g., depth to groundwater, soil type, and recharge)?	MPEP
3	To what extent can irrigated agriculture's impact on groundwater quality be differentiated from other potential sources of impact (e.g., nutrients from septic tanks or dairies)?	MPEP & GQTMP
4	What are the trends in groundwater quality beneath irrigated agricultural areas (getting better or worse) and how can we differentiate between ongoing impact, residual impact (vadose zone) or legacy contamination?	GQTMP
5	What properties (soil type, depth to groundwater, infiltration/recharge rate, denitrification/nitrification, fertilizer and pesticide application rates, preferential pathways through the vadose zone [including well seals, abandoned or standby wells], contaminant partitioning and mobility [solubility constants]) are the most important factors resulting in degradation of groundwater quality due to irrigated agricultural operations?	MPEP

TABLE 3-4. GROUNDWATER MONITORING ADVISORY WORKGROUP (GMAW) QUESTIONS IDENTIFIED IN THE GENERAL ORDER

GMAW Question ¹		Program Specified in General Order ²
6	What are the transport mechanisms by which irrigated agricultural operations impact deeper groundwater systems? At what rate is this impact occurring and are there measures that can be taken to limit or prevent further degradation of deeper groundwater while we're identifying management practices that are protective of groundwater?	MPEP
7	How can we confirm that management practices implemented to improve groundwater quality are effective?	MPEP

¹ See General Order page IS-13 (Central Valley Water Board, 2013)

² See General Order page IS-14, 4th paragraph and 6th paragraph (Central Valley Water Board, 2013)

The MPEP and GQTMP are very closely linked. Specifically, the MPEP supports the GQTMP by providing calculated constituent fluxes (e.g., volume and mass) through the vadose zone and into groundwater to assess ongoing impacts from agricultural operations, residual (vadose zone) impact, and legacy contamination issues. In turn, the monitoring data generated under the GQTMP supports the MPEP by providing feedback in the form of regional groundwater constituent concentrations to assess groundwater quality changes on a regional scale, and their response to changing management practices and other contributing factors.

Both programs include groundwater monitoring activities. The MPEP, as developed herein, will include monitoring of first-encountered groundwater at a few select sites, and will maximize use of existing wells to the greatest extent feasible (Section 3.8). It is expected that the emphasis of GQTMP monitoring will be on a mix of domestic, municipal, and agricultural water supply wells that do not target first-encountered groundwater.

3.9.2 EVALUATION OF GROUNDWATER MONITORING AS AN MPEP ASSESSMENT TOOL

This section evaluates groundwater monitoring as an MPEP assessment tool, including the concept of the contributing area of a well, practical contributing area considerations, concentration and mass loading, and management practices and groundwater quality.

3.9.2.1 THE CONCEPT OF THE CONTRIBUTING AREA OF A WELL

Groundwater constituents that have been linked to agricultural activities include N compounds, mineral elements (e.g., potassium, chloride, sulfate, phosphorous, calcium, and magnesium), and more recently, metals⁸. These constituents can impart a distinctive agricultural-chemical fingerprint to groundwater on a regional scale. Elevated concentrations of these constituents have become ubiquitous in shallow

⁸ Some metals may not be introduced by agricultural activities but become mobilized by processes that are facilitated by agricultural inputs to groundwater.

groundwater systems in agricultural landscapes, including some in the Central Valley, where irrigation is a major contributor to groundwater recharge.

In the absence of a unique identifier (i.e., a constituent present in groundwater that can be directly linked to a specific source), it is necessary to consider a well's source area when interpreting groundwater quality in the agricultural setting.

The source area of a well is the land area that contributes water to the well when recharge occurs through that land. To avoid confusion with sources of nitrate, salts, or other constituents introduced to groundwater, the source area will be referred to here as the "contributing area." The size of the contributing area depends on several variables, including the well's construction details, the rate and duration of groundwater extraction, physical properties of the aquifer, and hydrologic conditions. In the absence of pumping, the well's contributing area essentially becomes a line, referred to as the monitored contributing length, s^9 . The monitored contributing length in recharge-dominated hydrologic systems, such as those encountered in irrigated agricultural settings, can be conceptualized as follows (Harter et al., 2002) (Figure 3-14):

Equation 1:
$$s = d \frac{v}{r}$$

Equation 2:
$$v = K i$$

where,

- s = monitored contributing length [L]
- d = length of screen below water table [L]
- v = regional groundwater flow [$L \ t^{-1}$]
- r = recharge rate [$L \ t^{-1}$]
- K = hydraulic conductivity [$L \ t^{-1}$]
- i = horizontal gradient [$L \ L^{-1}$]
- (L = length)
- (t = time)

Equation 1 states that s increases linearly with increasing d and v , and it decreases nonlinearly with increasing r . Importantly, when r approaches zero (i.e., no recharge), s becomes infinitely large.

⁹ Conceptually, the width of the contributing area approaches zero when a well is not pumped (or practically the well diameter). However, even monitoring wells are pumped during purging and sampling activities. Also, due to non-steady groundwater flow directions, the contributing length is an area that contributes flow to the well.

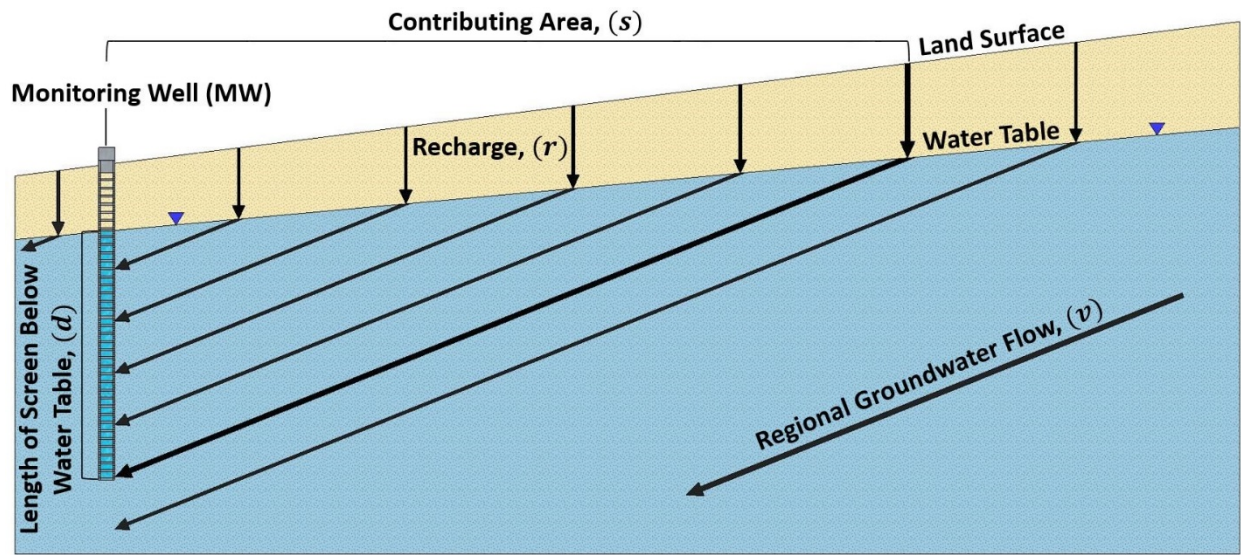


FIGURE 3-14. SIMPLIFIED SHALLOW AQUIFER CROSS-SECTION ALONG THE REGIONAL GROUNDWATER GRADIENT.

If uniform recharge rate, r , groundwater discharge rate, v , and length of screen below water table, d , are known, the size of the contributing area, s , can be estimated from equation 1 [from Harter et al., 2002; reproduced with permission from T. Harter; modified]. This figure illustrates the importance of considering the patterns of subsurface flow when installing monitoring wells. The surface area represented by samples pulled from the well depend on the well location and depths over which the well is screened.

Equation 1 represents a simplification of the actual system; in practice, the monitored contributing length is not constant. As water table elevations fluctuate, d and v change. Also, r fluctuates. Furthermore, groundwater flow direction (this is not included in the scalar form of K used in eq. 2) is variable. The single most influential variable on s is the hydraulic conductivity, K . This is due to the wide range of hydraulic conductivities, even for relatively homogeneous subsurface materials. The *Handbook of Hydrology* (Maidment, 1993) suggests the following ranges of K [m d^{-1}] for select earthen materials:

Clays:	$10^{-7} - 10^{-3}$
Silts:	$10^{-4} - 10^0$
Sands (fine to coarse):	$10^{-2} - 10^{+3}$

For typical values of d (10 ft), i (0.003), and r (1 ft y^{-1}), below are estimates of monitored source lengths (ft) for a range of K (ft d^{-1}) values (values are shown with one significant figure):

$K = 1$	$s = 10$
$K = 10$	$s = 100$
$K = 50$	$s = 500$
$K = 100$	$s = 1,000$
$K = 500$	$s = 5,000$

Notice the 10-order-of-magnitude overall range in these conductivities, and the four-to-five-order-of-magnitude range for each textural class. This is but one of the reasons for highly variable conductivities observed in real vadose zones and aquifers.

For a change in water quality observed in a monitoring well to be attributed to the effects of agricultural non-point sources (e.g., leaching of nitrate and salts below the crop root zone) under the prevailing management practices, the well's contributing area should reside entirely within the area where such practices are employed. This is illustrated in Figure 3-15, which conveys the concept that, in this setting, groundwater quality at the downgradient well is unrelated to groundwater quality at the upgradient well because the two wells have different contributing areas, and these areas do not overlap.

This contrasts with traditional groundwater monitoring at regulated (point-source) sites, where contaminants enter groundwater in a water volume that constitutes a very small fraction of the groundwater flowing beneath the site (i.e., not enough to be considered recharge). Also, these sites are often designed to minimize recharge via hardscape surfaces (e.g., leaks in underground gasoline storage tanks; Figure 3-16). Under such conditions, a downgradient monitoring well's contributing area extends beyond the investigated area. Its groundwater quality is interpreted as a mixture of groundwater, predominantly originating upgradient of the regulated site, and altered by a (small) contribution of often non-aqueous (e.g., petrochemical or volatile organic) compounds. The altered chemical composition (i.e., incremental impact) is then quantified by comparing downgradient to upgradient water quality.

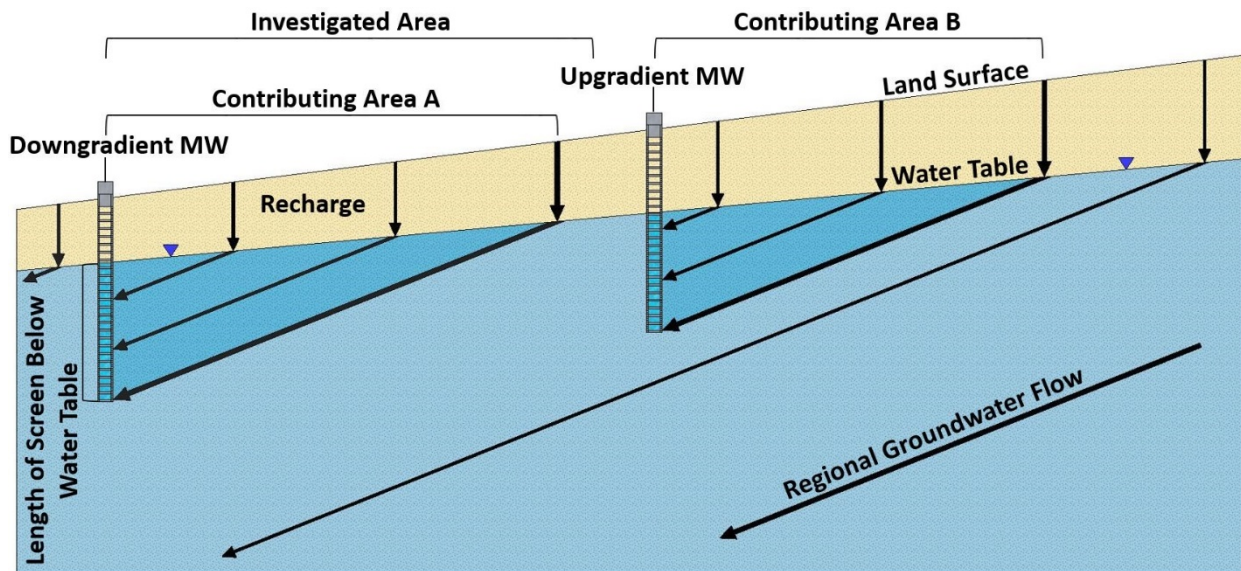


FIGURE 3-15. GROUNDWATER MONITORING FOR THE ASSESSMENT OF NON-POINT SOURCE EMISSIONS IN A RECHARGING HYDROLOGIC SYSTEM.

The investigated area should be larger than the contributing area. Downgradient and upgradient monitoring wells monitor groundwater that originates in two distinctly different contributing areas. Downgradient monitoring well is not affected by off-site, “ambient” conditions [from Harter et al., 2002; reproduced with permission from T. Harter; modified].

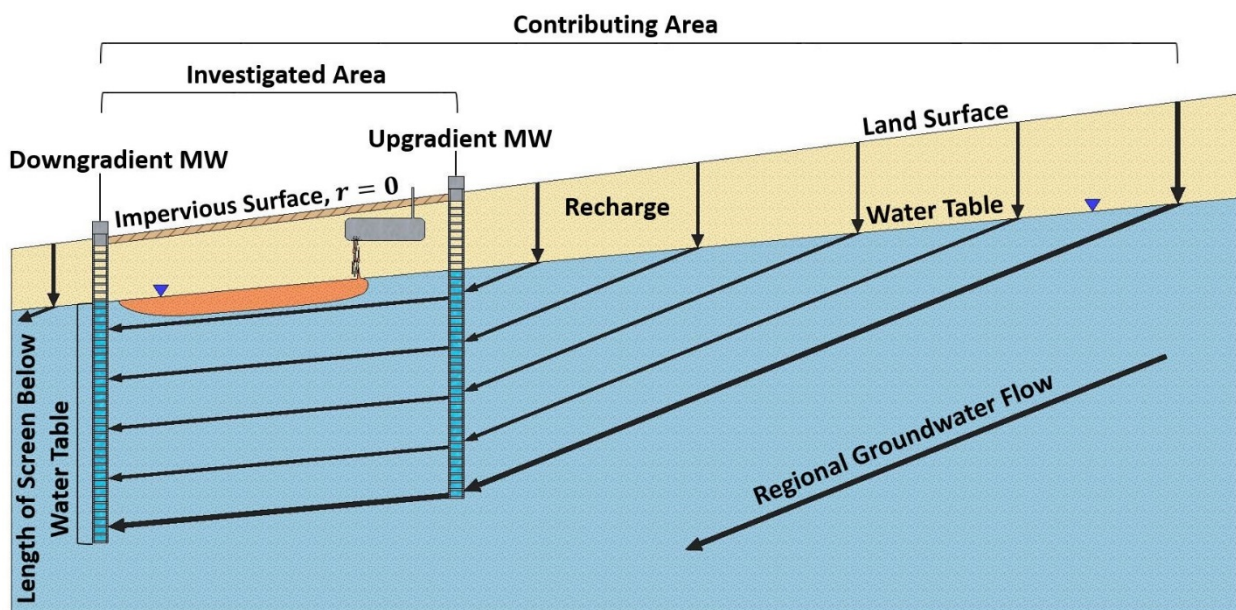


FIGURE 3-16. GROUNDWATER MONITORING FOR THE ASSESSMENT OF POINT SOURCE EMISSIONS IN A NON-RECHARGING HYDROLOGIC SYSTEM.

The investigated area is smaller than the contributing area. Downgradient and upgradient monitoring wells monitor the same contributing area upgradient of the investigated area where $r=0$. Downgradient monitoring well is affected by off-site, “ambient” conditions as affected by on-site point emissions [from Harter et al., 2002; reproduced with permission from T. Harter; modified].

3.9.2.2 PRACTICAL CONTRIBUTING AREA CONSIDERATIONS

This section describes practical considerations for designing monitoring wells intended to monitor conditions in first-encountered groundwater affected by agricultural non-point source emissions, and in the context of the MPEP. It also describes the effects of a thicker vadose zone (i.e., deeper first-encountered groundwater) on the interpretation of groundwater quality data.

When investigating contributing areas, monitoring well design options relate to the placement and length of the well screen. In practice, these options are limited. For example, the placement of the well screen is based on the occurrence of first-encountered groundwater during well construction. The longer the screen, the larger the contributing area from which water is intercepted. Therefore, with increasing screen length, groundwater quality increasingly represents an average over space *and* time (because travel times from distant points are longer than from nearer), which greatly confounds interpretation with regard to individual farming practices at the field scale. This is important because, were this not the case, a spatial average representing a large portion of the investigated area would arguably be ideal. However, unless transport in the unsaturated and saturated zones is extremely rapid, groundwater samples, even if representative of first-encountered groundwater, may be reflective of the effects of the sum of management practices employed over many years. Consequently, impacts to groundwater quality from managing a single crop (especially in double-cropped systems) may not be discernable in samples from a well with a relatively longer screen length.

As a corollary, a shorter screen intercepts a smaller contributing area. This tends to increase the variability of groundwater quality at a particular well due to the increasingly localized nature of the groundwater sample, which may or may not be reflective of the cumulative effect of management practices.

With increasing depth to first-encountered groundwater, the correlation of specific farming practices to groundwater characteristics becomes more difficult. As travel time through the vadose zone increases, the correlation between management practices and impacts to groundwater quality diminishes. Physical dispersion, including transport along preferential flow paths and lateral water movement above earthen materials of low hydraulic conductivity, causes the original signature of the percolate to be attenuated. Even when considering a theoretical, homogenous, and isotropic porous medium, dispersion moderates the pulses that are signals of individual irrigation and fertilization events and generates an aggregate signal that combines an unknown number of pulse signals, eventually over the course of years. In addition, reactive transport, including cation exchange, other sorption and desorption, oxidation, nitrification, and denitrification, have the potential to greatly change the chemical characteristics of percolate along flow paths before it reaches groundwater.

In summary, natural processes that become more important with increasing depth to groundwater (i.e., longer transport distances and times) impart technical limitations on the interpretation of groundwater monitoring results with respect to the groundwater's spatial and temporal origin or identity. These limitations cannot be alleviated by monitoring well design and will need to be considered when developing, executing, and interpreting investigations.

3.9.2.3 CONCENTRATION AND MASS LOADING

Under ideal conditions, a groundwater constituent concentration may yield information on the effect of a single source on groundwater quality at a specific point in the aquifer. However, groundwater monitoring results do not yield information on the source's subsurface mass emissions or loading rate. While improvements in agricultural practices, including improved nutrient use efficiencies, manifest themselves in reduced subsurface emissions, this reduction will not necessarily result in concentration decreases at the water table. Therefore, such reductions may not be detectable by groundwater monitoring. For example, increased water use efficiency, broadly accepted as a desirable goal for irrigated agriculture, directly increases concentrations of solutes (e.g., salinity, nitrate) in the percolate traveling below the crop root zone. For conservative minerals (salts), the basic physical relationship is as follows:

Equation 3:

$$C_d = \frac{C_i}{LF}$$

Equation 4:

$$LF = \frac{(AW - ET)}{AW}$$

where,

C_d = salt concentration in deep percolating water [mass/volume]

C_i = salt concentration in irrigation water [mass/volume]

LF = leaching fraction [unitless]

AW = applied water that infiltrates the soil [L]

ET = evapotranspiration [L]

Because this technical limitation applies to nitrate, improved nutrient management is expected to have a non-unique nitrate concentration signature at the water table. In other words, nitrate concentrations may rise, even as improved nutrient management reduces the mass of nitrate leached.

3.9.2.4 MANAGEMENT PRACTICES AND GROUNDWATER QUALITY

Growers use many combinations of management practices for growing crops. Within any particular combination, practices cumulatively have some effect on the nutrient use efficiency that is achieved, and in turn on leaching losses. For example, in a border-irrigated system, a grower may choose a certain field slope, irrigation onflow rate, and cultivation practice. This simplified system (slope "1", slope "2", harrowed vs. not harrowed, onflow rate "1" and onflow rate "2") already produces eight permutations of field conditions. While any one of these permutations may result in substantial irrigation water savings during pre-irrigation (and thus reduce leaching and improve nutrient use efficiency), it may or may not have an effect during the first irrigation or any subsequent irrigations over the course of one growing season. Other factors that may profoundly influence findings include the run length, antecedent soil-water conditions, check width, and soil type. Further, even subtle soil (textural) differences on adjacent fields or within fields can produce significantly different results in replicated trials. Finally, in practice, the management system is much more complex because there are different types of harrows and other implements available to modify surface roughness, and both slope and onflow rate provide many more options than used in this example.

Required Outputs and Data Quality for Groundwater Monitoring and Anticipated Uses of Results

This component of the MPEP technical workflow contributes to meeting the following MRP requirements:

- *The Workplan must include a scientifically sound approach to evaluating the effect of management practices on groundwater quality. The proposed approach may include: groundwater monitoring; modeling; vadose zone sampling; and/or other scientifically sound and technically justifiable methods for meeting the objectives of the Management Practices Evaluation Program.*
- *Where groundwater quality monitoring is proposed, the Management Practices Evaluation Workplan must identify the constituents to be assessed, and the frequency of the data collection (e.g., groundwater quality or vadose zone monitoring; soil sampling) for each constituent.*
- *Upon approval of the Management Practices Evaluation Workplan, the third party shall prepare and submit a Monitoring Well Installation and Sampling Plan (MWISP), if applicable.*

Results will inform understanding of the causal relationships between management practices (i.e., the Landscape-level Performance Assessment from Section 3.10) and groundwater conditions

Lastly, it is important to recognize that a management practice may have much less of an effect on groundwater quality than the actual day-to-day decisions associated with a given practice. For example, the determination of cutoff time based on visual observation of the irrigation water advance across the check is a common practice with surface irrigation systems. The decision for cutoff has to be made check-by-check, many times during the irrigation season, while balancing the need to irrigate the entire field with the desire to minimize leakage losses. Yet, the degree to which this decision optimizes competing goals (i.e., meet crop water requirement, but minimize leakage loss while maintaining sufficient flushing of salts from the root zone) can vary widely. Thus, although many management practices (e.g., optimize cutoff time) appear to be categorical in nature, they are much more complex and nuanced in the real world. The categorical concept is consistent with a rather straightforward evaluation of a practice's impacts on groundwater quality. However, due to the complexity of the real world, on-farm implementation of a practice is often variable through time. The overall effects of such implementation decisions on groundwater quality are expected to exhibit very large variability. This variability, along with the inherent spatial variability of the environment in which farming takes place, will need to be considered when developing, executing, and interpreting investigations.

3.9.3 MPEP GROUNDWATER MODELING

A groundwater modeling tool will likely be needed to link the results of modifications in management practices to the protection and/or improvement of groundwater quality at spatial and temporal scales associated with long-term beneficial uses of the aquifer system. The scope of an MPEP groundwater modeling effort and its interaction with the GQTMP will be delineated during MPEP implementation. Models or model components, including conceptual, analytical, empirical, stochastic, and numerical approaches, will be identified based on the functions these models will serve within the overall MPEP effort.

3.9.4 SUMMARY RATIONALE FOR A MULTI-PRONGED APPROACH

Agricultural improvements in nutrient use efficiency manifest themselves in the reduction of nitrate leaching risk to groundwater, but not necessarily in concentration decreases in the water table. In fact, non-unique concentration responses, including concentration increases at the water table, are expected as a consequence of increased water use efficiencies. Therefore, monitoring first-encountered groundwater quality does not develop the information that the MPEP needs to address the General Order's overall goal and objectives. Nonetheless, it is an important component of the multi-pronged approach presented herein.

To establish reasonable levels of confidence in causal relationships between management practices associated with different conditions (e.g., crops, soils, irrigation systems, etc.) and chemical concentrations in groundwater, groundwater monitoring activities need to focus on hydrologic areas characterized by rapid movement through the unsaturated and saturated zones, and minimal reactive transport (Section 3.8.2). This limits the geographic area and, consequently, reduces the selection of cropping systems available for this effort. Therefore, a separate effort will precede the preparation of a Monitoring Well Installation and Sampling Plan (MWISP) to identify a few sites suitable for MPEP groundwater monitoring (Section 3.9.5). Existing wells will be used to the greatest extent feasible.

The flexibility to investigate many combinations of management practices under different site conditions and hydrogeologic conditions is most feasible with data-supported vadose zone modeling. Management practice evaluation will be supported by nutrient accounting at the land surface. The combined data collection and modeling effort intends to address the MPEP's overall goal and objectives as stated in the General Order. The primary purpose of monitoring first-encountered groundwater is to increase confidence in vadose zone model results (and facilitate adjustments to model parameters, as needed) by providing a means to check flux and concentration output from vadose zone models against field observations at a few select sites with favorable hydrologic conditions (Section 3.8.2).

3.9.5 IDENTIFICATION OF AREAS SUITABLE FOR MPEP GROUNDWATER MONITORING

This section describes the methods that will be used to identify a few select sites with favorable conditions for monitoring first-encountered groundwater. Existing wells will be used to the greatest extent feasible.

3.9.5.1 METHODS

The methodology includes the following:

- Use and organization of readily available pertinent data
- Identification of favorable conditions for monitoring of first encountered groundwater
- Use of spatial analyses that use a GIS database and mapping tool.

The following four data types will be analyzed: land use information, depth to groundwater, recharge to groundwater, and soil survey information (e.g., vertical saturated hydraulic conductivity).

3.9.5.1.1 LAND USE INFORMATION

Areas with representative crops and/or commodity groups (Section 3.5.1.1) will be identified based on land use data available for the entire MPEP area.

3.9.5.1.2 DEPTH TO GROUNDWATER

The depth to first-encountered groundwater gives an indication of the thickness of the unsaturated zone, which can give an indication of the comparative sensitivity of groundwater to surface water percolation. For example, a thin unsaturated zone may be expected to provide less protection for groundwater resources than a thick unsaturated zone, which provides greater opportunity for natural attenuation to occur (when other variables are constant). The thickness of the unsaturated zone can also provide an indication of the relative travel time of vertical unsaturated flow to reach groundwater. Therefore, the depth to groundwater is an important component within the framework of the proposed methodology.

Data sources might include the following:

- Coalition GARs
- CVHM
- DWR
- Kings Sub-basin Integrated Water Flow Model (IWFM)

Hydraulic head output files would be drawn from CVHM, Kings Sub-basin IWFM and DWR's mapped contours of equal depth to first-encountered groundwater (identified as the unconfined aquifer). CVHM output synthesizes the relative effects of a large number of environmental variables estimated over the entire Central Valley (e.g., three-dimensional subsurface grain size distribution, vertical hydraulic conductivities, evaporation, topography (slope and aspect), precipitation, streamflow, land use, irrigation applications, and crop root depths). Numerical values are available (i.e., facilitates quantitative analysis as opposed to categorical comparison). Simulated groundwater levels from CVHM were checked against field measurements during calibration. However, CVHM output and DWR data are spatially coarse, and thus not applicable for site-specific assessment due to large-scale averaging.

3.9.5.1.3 RECHARGE TO GROUNDWATER

The rate of recharge represents the link between surface water and groundwater and gives an indication of aquifer vulnerability to surface water percolation. Under certain assumptions and a given constituent concentration, the rate of recharge determines the constituent's mass loading rate to groundwater. For example, an area of low groundwater recharge is expected to be less vulnerable to contamination from surface water percolation than an area of high recharge (other variables constant). Therefore, knowledge of the vertical flux to groundwater is a useful component within the framework of the proposed methodology.

Coalition GARs could provide some information related to recharge. In addition, CVHM and IWFM could provide Vertical flux data. These sources synthesize the relative effects of a large number of environmental variables over the entire Central Valley (e.g., three-dimensional subsurface grain size distribution, vertical hydraulic conductivities, evaporation, topography (slope and aspect), precipitation, streamflow, land use, irrigation applications, and crop root depths). Numerical values are available (i.e., facilitates quantitative analysis as opposed to categorical comparison).

The following limitations are inherent in these data: simulated recharge is not checked against field measurements during calibration; extraction and compilation of cell-by-cell output data is time consuming; and data may not always be applicable for site-specific assessment because the modeled quantity is subject to large-scale averaging.

3.9.5.1.4 SOIL SURVEY INFORMATION

Soil survey information includes saturated vertical hydraulic conductivity data that affects the potential for leaching and the potential availability of oxygen in shallow groundwater, which affects the fate of N components. These data can be obtained from SSURGO, in which extensive, detailed soil descriptions are compiled. These are applicable to a maximum depth of 6 feet. Transport through soil layers at the landscape level can be assessed with various root-zone models (Section 3.10).

SSURGO data coverage is excellent throughout the MPEP area, and the data are based on extensive field observations, sample collection, and laboratory analyses. However, the sheer volume of data makes the database challenging to manage and interpret. Fortunately, USDA-NRCS has recently developed powerful ArcGIS toolsets that greatly facilitate this.

3.9.5.2 SELECTION OF INDIVIDUAL SITES

The results of the analysis will be presented in a technical memorandum outlining areas of interest. In collaboration with growers, specific sites within the areas of interest will be selected through consideration of additional parameters such as site-specific irrigation systems, the agricultural history of the land, and the existence and functionality of on-site monitoring wells.

3.9.6 MONITORING WELL INSTALLATION AND SAMPLING PLAN

Based on the results of the effort described in Section 3.9.5, a MWISP will be prepared in compliance with Appendix MRP-2 of the General Order. The MWISP will consider findings in the GARs, as appropriate, to devise the sampling plan. At a minimum, baseline constituents will include those parameters required under trend monitoring as required in Attachment B, Section IV.D.2 of the General Order. Ultimately, the scope of constituent sampling and sampling frequencies will be developed under consideration of site-specific conditions including the hydrogeologic setting, the farming operations being investigated, and the scope of the associated aboveground and vadose zone investigation.

Required Outputs and Data Quality for Landscape-level Performance Assessment, and Anticipated Uses of Results

This component of the MPEP technical workflow contributes to meeting the following MRP requirements:

- *Determine if newly implemented management practices are improving or may result in improving groundwater quality.*
- *Determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions) need to be improved.*
- *The Workplan shall contain sufficient information to evaluate the ability of the evaluation program to identify whether existing management practices in combination with site conditions, are protective of groundwater quality.*

In addition to meeting reporting requirements under the Order, results of this evaluation of N losses under current conditions and assessment of BMP application across the MPEP area will a) feed directly into Outreach (see Sections 2.4 and 3.11), and b) inform monitoring and research plans.

3.10 LANDSCAPE-LEVEL PERFORMANCE ASSESSMENT

Information developed within the previously described Workplan elements will ultimately be used to estimate N losses from irrigated lands across the landscape within the MPEP area. This effort will be based on data collected by the coalitions and from other sources. Regional and temporal variations in N losses need to be understood to assess the need for and potential effects of BMP adoption. This assessment will also allow the MPEP Team to revisit and further refine the prioritizations developed in the coalitions' GARs.

Because the interactions between water, soil, plants, nitrogen, and the atmosphere are very complex and highly variable over time and space, attempts to quantify nitrate fluxes require a modeling framework that simulates water and N balances across the soil-plant-water-atmosphere continuum. In addition, the modeling framework must also incorporate spatial factors to quantify nitrate fluxes at scales ranging from field to watershed. SWAT (Neitsch et al., 2009) is a modeling framework that integrates crop production and physical data, producing output for the entire landscape, but specific down to relatively small spatial units of analysis (field or sub-field). For these and other reasons, SWAT has been selected as the central analysis tool to evaluate the influence of management practices on N losses and crop production. The use of SWAT does not, however, preclude use of other tools and models for focused investigations and to check SWAT results, as appropriate.

The landscape-level performance assessment will be conducted in three primary steps (Figure 2-2):

1. Initial SWAT models will be developed to characterize the potential ranges of N loading based upon readily available information.
2. SWAT models will be refined by comparison with the results of field studies and benchmark N balance and N surplus data.

3. Updated SWAT models will be used to evaluate the effects of actual and hypothetical levels of BMP implementation across the MPEP area.

In the following discussion, the SWAT model is introduced and described, and an initial SWAT model run is presented for a portion of the MPEP area. Finally, a process for conducting modeling work is described.

3.10.1 INTRODUCTION TO THE SWAT MODEL

SWAT is a spatially distributed, continuous, daily-time-step, hydrological model developed by USDA Agricultural Research Services to predict the impact of crop/land management practices on water quality, sediment and agricultural chemical losses to the environment in watersheds with heterogeneous soils, land use, and management conditions. Inputs for weather, soil, topography, vegetation, and land management practices drive the various biophysical processes associated with water quality and movement, sediment transport, crop growth, nutrient cycles, pesticide fate, energy balance, chemical and microbial dynamics, and water impoundments. A graphical user interface for the SWAT model called ArcSWAT is available as an extension to ArcGIS software for convenient input of widely available climatic, topographic, soils, and other data, as well as spatial and other analysis of output. SWAT software, documentation, and other details are free and public domain, available at <http://swat.tamu.edu/software/>. The platform is open to customization of sub-models that may be necessary (for example) to accurately reflect unique attributes of the highly productive Central Valley cropping systems.

Several factors influence the transport of nitrogen, including soil texture, form/placement/rate/timing of N application, precipitation and irrigation amounts, and crop uptake of water and nitrate. Figure 3-17 shows the major components of the N cycle simulated by SWAT. SWAT tracks five different pools of nitrogen: two inorganic forms of nitrogen (NH_4^+ and NO_3^-), and three organic pools. Fresh organic nitrogen is associated with crop residue and microbial biomass, while the active and stable organic N pools are associated with the soil humus. SWAT simulates N fixation by legumes when the soil does not supply the plant with enough nitrogen for growth. Nitrate is an anion, not attracted to or sorbed by soil particles (unless significant anion exchange capacity exists, which is uncommon in the Central Valley) and hence is susceptible to leaching. The algorithms used by SWAT to calculate nitrate leaching simultaneously solve for loss of nitrate in surface runoff and lateral flow.

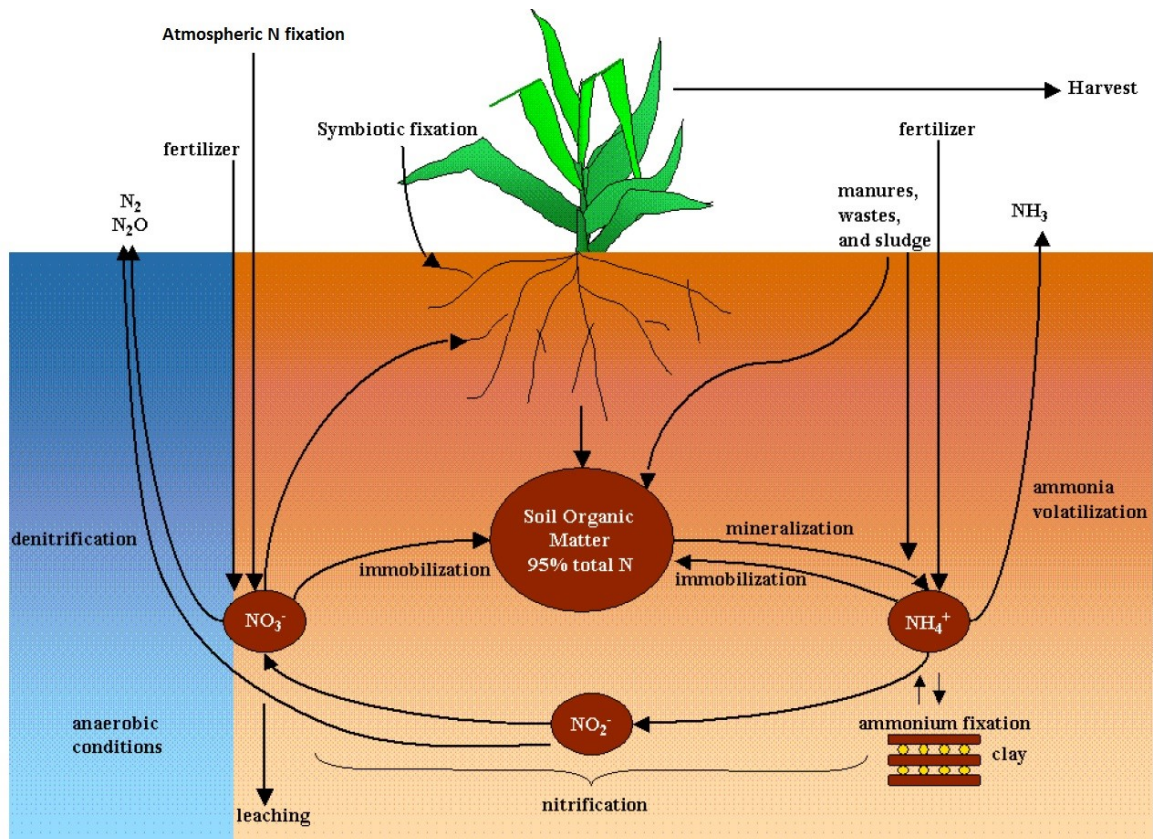


FIGURE 3-17. NITROGEN CYCLE PROCESSES SIMULATED IN SWAT MODEL

SWAT uses plant growth models based on heat units to simulate the different land cover/crop classes. These models drive removal of water and nutrients from the root zone based on crop growth driven by temperature, water, and nutrient supply. SWAT categorizes plants into seven broad classes with the following characteristics:

1. Warm season annual legume
 - (a) Simulate N fixation
 - (b) Root depth varies during growing season due to root growth
2. Cold season annual legumes
 - (a) Simulate N fixation
 - (b) Root depth varies during growing season due to root growth
 - (c) Fall-planted land cover will go dormant when day length is less than the threshold day length

3. Perennial legume
 - (a) Simulate N fixation
 - (b) Root depth always equals the maximum allowed for the plant species and soil
 - (c) Plant goes dormant when day length is less than the threshold day length
4. Warm season annual non-legume
 - (a) Root depth varies during growing season due to root growth
5. Cold season annual non-legume
 - (a) Root depth varies during growing season due to root growth
 - (b) Fall-planted land cover will go dormant when day length is less than the threshold day length
6. Perennials other than tree crops
 - (a) Root depth always equals the maximum allowed for the plant species and soil
 - (b) Plant goes dormant when day length is less than the threshold day length
7. Tree crop
 - (a) Root depth always equals to the maximum allowed for the plant species and soil
 - (b) Partition new growth between leaves/needles and woody growth
 - (c) Growth in a given year will vary depending on the age of the tree relative to the number of years required for full development/maturity
 - (d) Plant goes dormant when day length is less than the threshold day length

The land cover/plant species database contains information needed by SWAT to simulate the growth of 120 crop types. Generic land cover attributes could be used to develop new plant parameter values for crops (or crop parameters) not available in the database. The growth parameters in the plant growth database define plant growth under ideal conditions and quantify the impact of some stresses on plant growth. Plant growth may be reduced due to water stress, temperature stress, N and phosphorus deficiency (each of them computed on a daily basis). SWAT accommodates detailed crop management information that controls the plant growth cycle. Management factors simulated include crop rotation, timing and type of fertilizers and pesticides, manure management, tillage operations, grazing operations, water management and removal of plant biomass and yield.

Some California cropping systems are unique and extremely productive. Sometimes crop models developed in other regions do not have the productivity range to accurately represent these systems. In

these cases, existing crop models will need to be modified to better reflect the high-intensity, high-yield cropping systems as implemented in California's Central Valley.

The smallest modeling unit in SWAT is a hydrological response unit (HRU), which is a land area within a sub-basin comprised of a unique combination of land cover, soil, and slope. SWAT simulates hydrology at the watershed/sub-basin scale with each subarea linked according to the water routing direction in the watershed, starting from the most distant sub-basin towards the watershed outlet. Infiltrating water and solutes are analyzed by simulating hydrologic, biological, and physical root-zone processes. Root-zone outputs include nitrogen and water balance components, including percolation and leaching below the root zone. Otherwise, water, sediment, nutrient, and pesticide loadings to the main channel in each sub-basin are then routed through the channel networks. Routing mechanisms allow for evaluation of interactions between subareas for surface runoff, return flow, sediment deposition and degradation, nutrient transport, and groundwater flow, as well as the collective evaluation/analysis for all subareas. Water quality in terms of nitrogen (NH_4 , NO_3 , and organic), phosphorus (soluble and sorbed/mineral and organic), and pesticide concentrations is estimated for each HRU. The model operates on a daily time step assimilating the changes in daily weather and specific timing and application of management practices, and simulates physical, biological and environmental processes. Simulations can examine timeframes from one year to hundreds of years, depending on needs of the study. Results can be evaluated on daily, monthly, and yearly time steps.

3.10.1.1 REVIEW OF SWAT LITERATURE FOR NITROGEN TRANSPORT MODELING

There are 2,402 peer-reviewed articles on SWAT; a complete online literature database is provided at https://www.card.iastate.edu/swat_articles/index.aspx. SWAT is a globally adopted tool for monitoring and managing ecological, hydrological, and agricultural processes from a small watershed to continental scale. The literature shows its application over a wide array of categories ranging from sediment yield, nutrient transport, streamflow gauging, groundwater recharge, water quality, impact of agricultural operation, climate change impact, etc. In a European Union project on benchmarking models, SWAT was tested for its suitability to assess management options proposed to meet surface-water-quality targets. The study concluded that SWAT includes relevant management options that affect nutrient leaching; the study also stated that the description of management options requires modifications to describe correctly the reduction efficiency in local conditions (Barlund et al., 2007). To address high nutrient loading from agriculture, SWAT was used in a watershed in France to identify the major processes and pathways controlling nutrient losses (Bouraoui and Grizzetti, 2008). In a study of a dairy farming watershed in Japan, it was demonstrated that SWAT is an appropriate method to determine the temporal and spatial patterns of NO_3^- -N export from the watershed. SWAT was used to identify the polluted areas within the watershed and showcased improved management practices to more effectively control NO_3^- -N export to water bodies (Jiang et al., 2015).

Additionally, the model has been adopted as part of the United States Environmental Protection Agency's Better Assessment Science Integrating Point and Nonpoint Sources (known as BASINS) software package for applications including support of Total Maximum Daily Load analyses. SWAT also is being used by many federal and state agencies, including USDA within the Conservation Effects

Assessment Project, to evaluate the effects of conservation practices. SWAT already has an established method for modeling several agricultural practices, including changes in fertilizer and pesticide application, tillage operations, crop rotation, dams, wetlands, and ponds. The model has the capacity to represent many other commonly used practices in agricultural fields through alteration of its input parameters.

In addition to this application for the LTILRP, SWAT is being used for other purposes in California, adding to the community of users, level of refinement, local knowledge base, and Central-Valley-specific input and output data sets. These applications include (at least) the following:

- California Department of Pesticide Regulation, who are employing SWAT to examine fate and transport of agrichemicals.
- California Department of Water Resources' Sustainable Groundwater Management Act work, in which the use of SWAT is being investigated for characterizing landscape-level water balances.
- CV-SALTS, where SWAT was used to quantify percolation and nitrate loading to groundwater in, Alta Irrigation District (AID, in Kings County) under four irrigation and fertilizer management scenarios. In this application, output was post-processed to analyze fate of applied salinity. In addition to irrigated lands, additional sources, such as industrial, dairy, and septs were studied, so that water quality relationships of irrigated lands were assessed in a realistic context. This effort can be readily expanded to provide a reasonably good starting point for modeling fate and transport of nitrate at the landscape level across the SSJV MPEP area.

The literature thus strongly suggests that SWAT offers good range and flexibility for modeling the influence of management in agricultural watersheds.

3.10.1.2 INITIAL SWAT MODEL FOR A PORTION OF THE SSJV MPEP AREA

ArcSWAT requires most inputs to be in compatible raster and vector (shapefiles and feature classes) formats, geographically projected into the underlying coordinate system. Table 3-5 lists the inputs used for setting up the model for the AID area. Weather data for 32 years (1983-2014) enabled long-term simulation and provided the required model initiation and stabilization time. Figure 3-18 shows the watershed extent with the SSJV MPEP area. Figure 3-19 shows the 3,633 HRUs generated from the unique land cover, soil, slope combinations. Figures 3-20 and 3-21 show the 42 land use classes and 92 soil classes, respectively, in the SSJV MPEP area.

TABLE 3-5. INPUTS TO SWAT MODEL FOR THE ALTA IRRIGATION DISTRICT

Sl. No.	Dataset	Source	Remarks
1	DEM raster file	SRTM 30 meter	DEM is used in the watershed delineation
2	Land Cover/ Land Use shapefile	DWR	Land use map classified into 39 classes
3	Land use look up table	--	Text file to connect land use classes to SWAT crop database

TABLE 3-5. INPUTS TO SWAT MODEL FOR THE ALTA IRRIGATION DISTRICT

Sl. No.	Dataset	Source	Remarks
4	Soil raster dataset	STATSGO soil dataset	
5	Climate data: Precipitation, Minimum and Maximum Temperature, Solar Radiation, Wind Speed and Relative Humidity	CIMIS weather stations	Daily data from 1983-2014 for 23 stations in and around the MPEP area

DEM: Digital Elevation Model

CIMIS: California Irrigation Management Information System

SRTM: Shuttle Radar Topography Mission

STATSGO: State Soil Geographic dataset

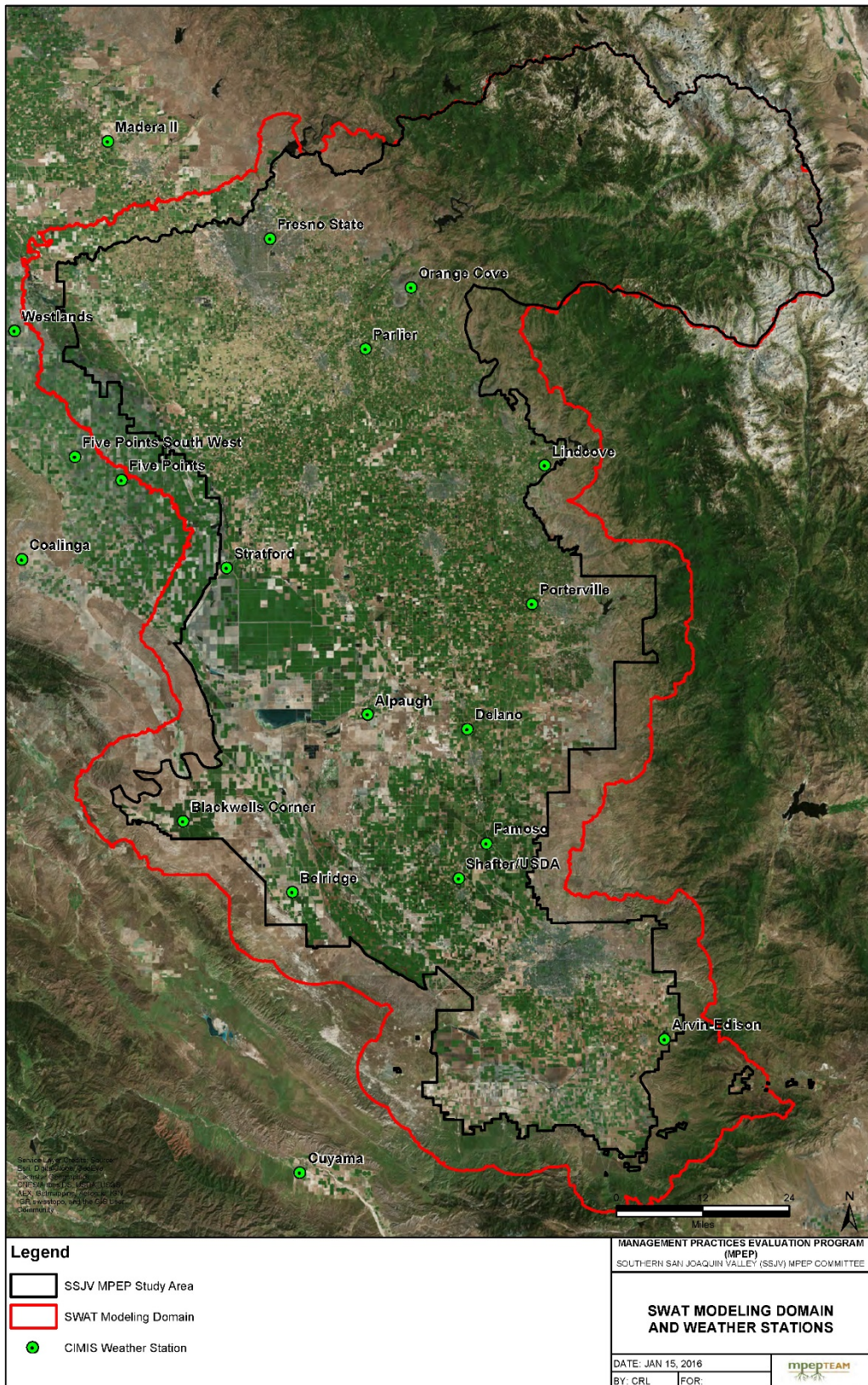


FIGURE 3-18. SWAT MODELING DOMAIN AND WEATHER STATIONS

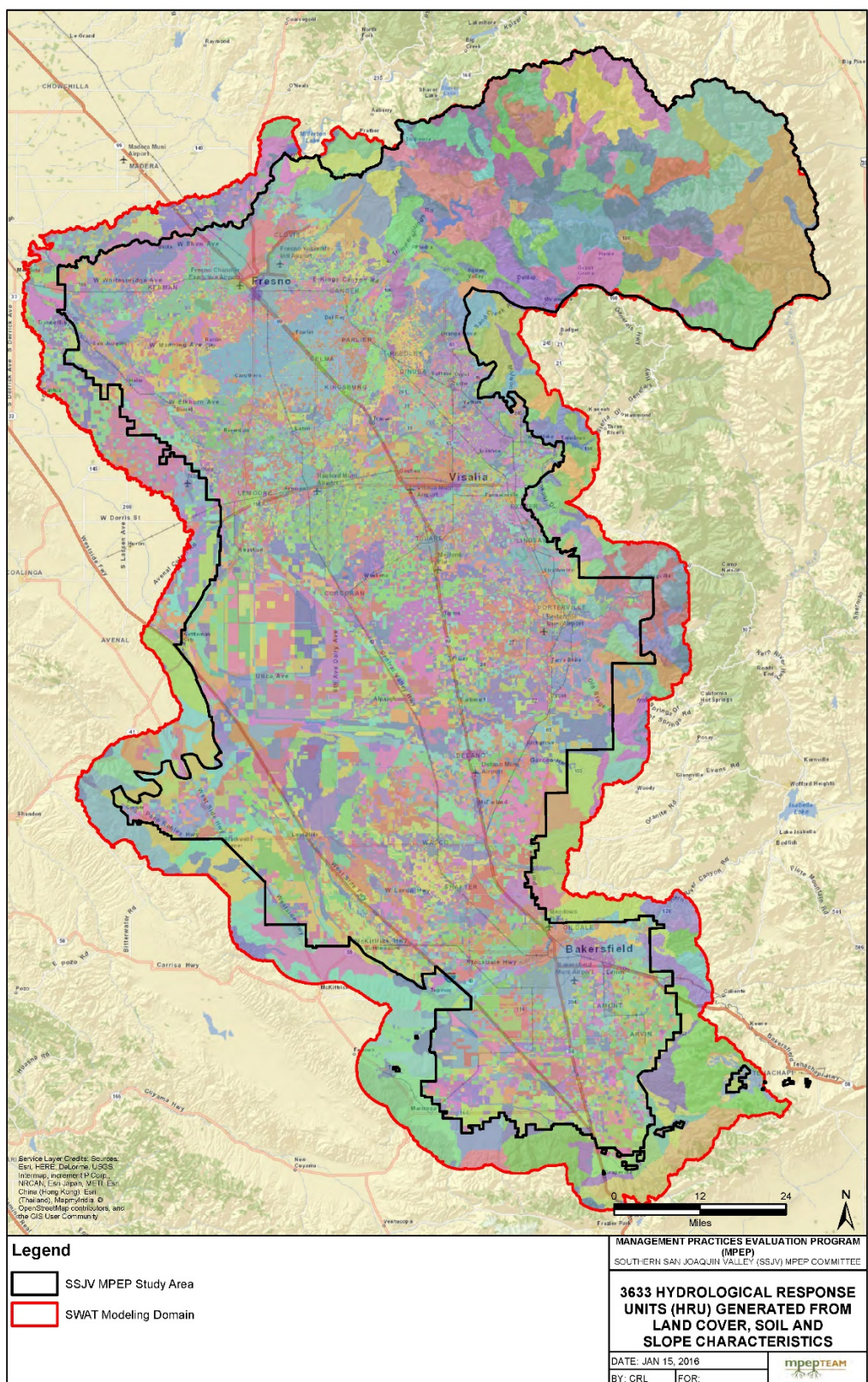


FIGURE 3-19. HYDROLOGICAL RESPONSE UNITS GENERATED FROM THE UNIQUE LAND COVER, SOIL, AND SLOPE COMBINATION

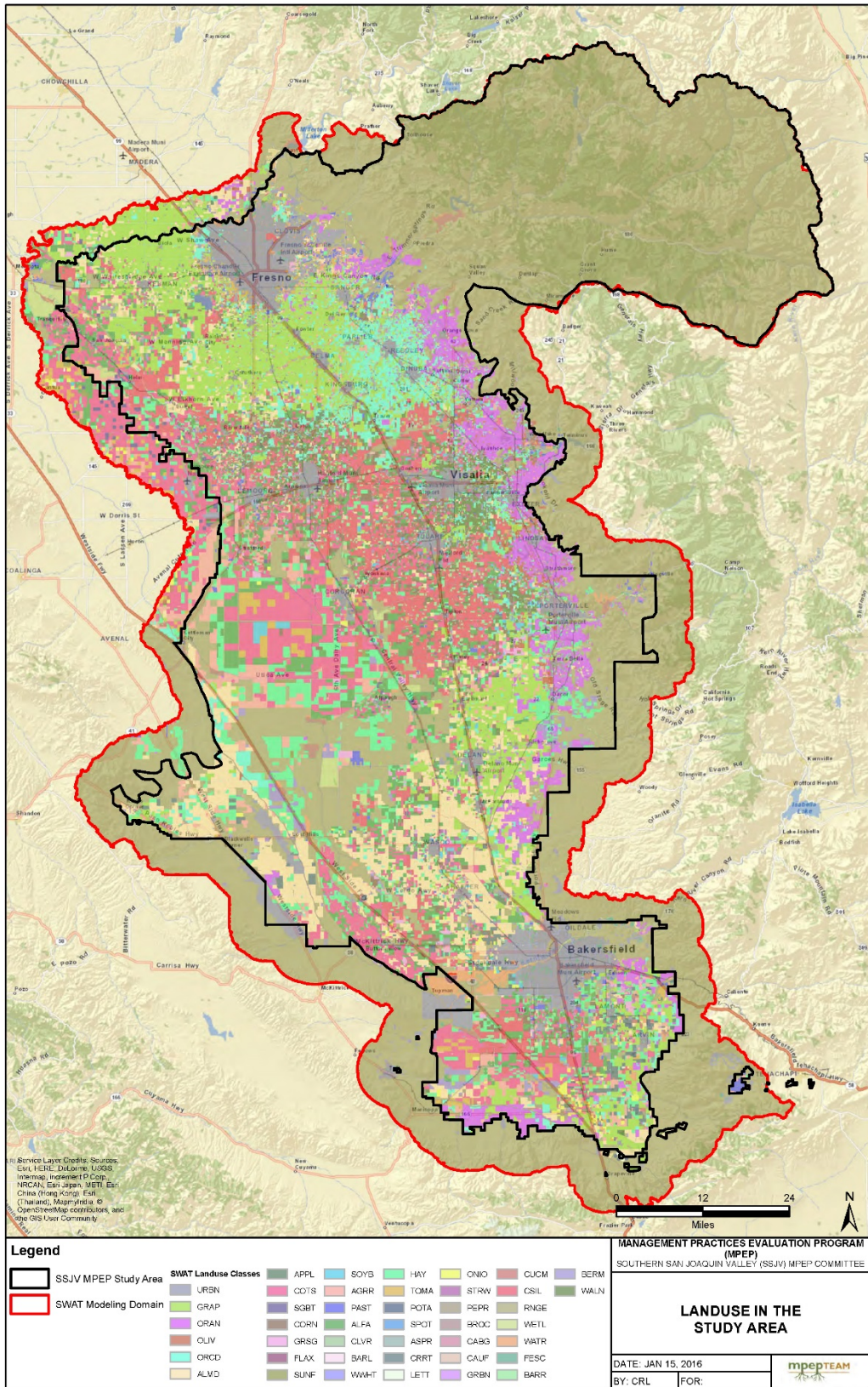


FIGURE 3-20 LAND USE IN THE MPEP AREA

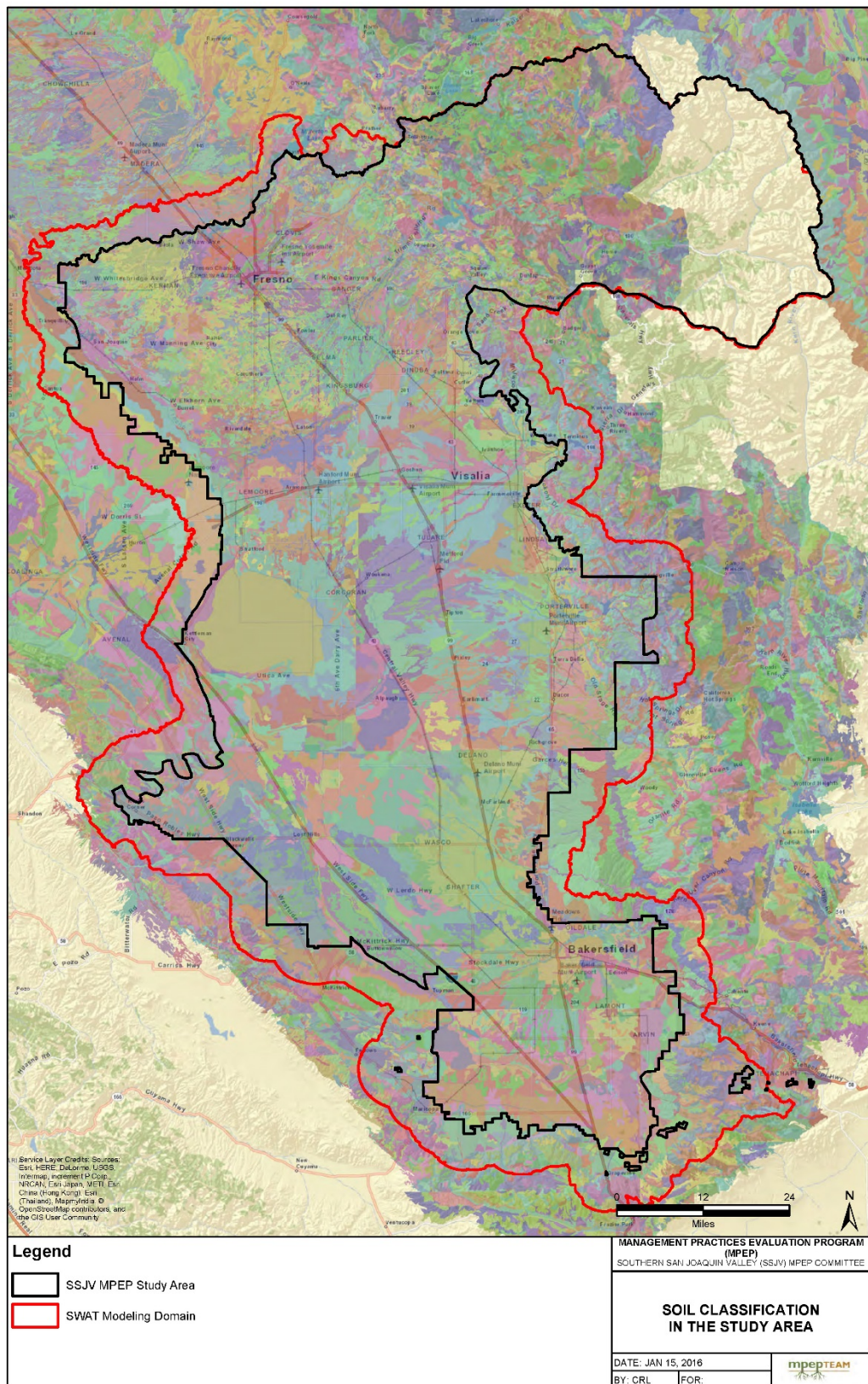


FIGURE 3-21. SOIL CLASSIFICATION IN THE MPEP AREA

3.10.1.3 PROCESS TO FURTHER DEVELOP THE SWAT MODEL FOR THE MPEP

As described in Section 3.10.1 and shown on Figure 2-2, the MPEP will take a three-phase approach to the landscape-level performance assessment with the SWAT model. Each phase is described in the following sections.

3.10.1.3.1 INITIAL SWAT MODELS DEVELOPMENT

In this first phase, the initial SWAT models developed for the AID area will be adapted for use in the MPEP. This adaptation will incorporate the spatial and time series data from the irrigated lands characterization (Section 3.5) and will also incorporate the cropping characterization initial N balance and N surplus data from the source quantification efforts (Section 3.6). This information will be integrated to characterize the potential ranges of N loading and losses based upon readily available information.

3.10.1.3.2 SWAT MODEL REFINEMENT

In parallel with and following the initial prioritization of investigations (Section 3.7) and the focused field studies (Section 3.8), the SWAT models will be refined using the new information obtained through these efforts. Data collected that can support additional SWAT crop submodel calibration and performance evaluation will be considered. This process will allow for locally derived information to be incorporated, thereby increasing the precision of the regional model estimates.

Specific refinements that are anticipated include the following:

- Incorporation of more detailed SSURGO (soil survey) data to upgrade from STATSGO (more general soil information) data employed for the AID analysis.
- Revision of several crop growth models (e.g., almonds, processing tomatoes) to allow them to better reflect intensive, high-yielding systems that are common in the Central Valley.
- Development of an integrated salinity submodel to replace the post-processing model developed for the AID work.
- Refinement of crop-specific and irrigation management parameters with assistance from technical collaborators.
- Development of a greater and more representative range of management practice combinations for major crops.
- Checking and calibration of SWAT model output against field study results.
- Validation of model predictions by comparison with field monitoring results.

3.10.1.3.3 SWAT MODEL APPLICATION ACROSS MPEP AREA

After the refinement of the SWAT crop submodels using the information described above, SWAT will be used to assess landscape level N losses. The same runs can then be repeated with different suites of

management practices. This will allow the MPEP Team to evaluate N losses under current conditions and to assess the effects of further BMP application across the MPEP area.

3.11 SHARING FINDINGS WITH COALITION MEMBERS (OUTREACH)

The Committee's approach to outreach was presented in Section 2.4. In actual practice, the use of the themes of information and communication conduits will need to be planned and scheduled. Committee members and their coalitions' memberships, with their existing relationships and collaborators, will facilitate outreach and participation. Outreach events are shown in the Master Schedule (Figure 3-1) to follow each major phase of investigation. The first will begin almost immediately, and will be informed by an initial inventory of known protective practices. CDFA's FREP, a program largely funded by mill taxes on fertilizer purchases, has extensive infrastructure and experience in organizing and delivering high-quality outreach activities. They tend to work with the same technical collaborators as employed in the MPEP. Furthermore, their focus on controlling environmental fate of applied fertilizer aligns almost perfectly with the goals of the MPEP. Crucially, FREP has been a key collaborator in developing this Workplan, and is committed to supporting the MPEP outreach effort.

The Committee has already drafted (and will soon post) a Grower/Advisor Webpage on its web site, which includes an organized collection of many useful tools and references that already exist. This site will be updated as additional information becomes available from the Committee, member coalitions, partners (including the Central Valley Water Board), and other sources. This handy collection of resources for minimizing loss of applied nitrogen to groundwater will be available not only to member growers, but to growers and grower advisors anywhere. The Committee hopes that such a grower-oriented collection, focused on means to address this problem through sound management, will help growers actually apply these solutions in their practices on their fields, which must be done for actual benefits to be realized.

Additional online tools, information, and applications will be developed to meet specific needs. For example:

- Helpful information for growers and their advisors to efficiently derive maximum benefit from required Nitrogen Management Planning processes can be provided.
- Tools to facilitate second-language growers to understand and comply with LTILRP requirements and derive maximum water quality and production advantages.
- Query-able management practice databases to assist growers in evaluating the potential cost and benefits (production, water quality, labor) benefits of various suites of management practices, applied at their specific management block locations and planting dates.

Committee partners include the many organizations listed in Section 2.4, a number of which hold and/or participate in annual (generally wintertime) meetings at which information on managing crops, including protective planting, fertilization, and irrigation practices, is shared. Activities spurred by the Committee will focus, intensify, and increase the rate at which this annual information sharing produces new

knowledge, and influences grower practices. Coalitions will work with collaborators to reinforce and supplement existing outreach programs with additional online or live meetings, or educational resources, as necessary to meet the goals of the MPEP.

As mentioned previously, the initial inventory of management practices will result in a list of known, protective practices that will move immediately into this outreach process. It will be discussed with advisors and growers during 2016-17 meetings. Information on these practices will also be featured in an organized, accessible fashion on the Grower/Advisor Webpage, which water quality coalition membership will be encouraged to consult.

As required by the General Order, outreach products and activities will be documented and shared with the Central Valley Water Board in regular communications such as quarterly meetings and as part of required reporting.

3.12 ASSESSING ADOPTION, DATA EXCHANGE WITH COALITIONS

As mentioned in Section 3.2, the irrigated agricultural landscape is so vast that, in practical terms, monitoring alone cannot provide adequate assurance that groundwater quality is protected. Rather, once protective practices for specific irrigated lands settings (unique crop, soil, and management combinations) are identified under the MPEP, the increasing frequency of those practices on the landscape will demonstrate MPEP progress. Documentation of trends in the application of practices is therefore essential to demonstrate protection of groundwater quality.

At present, reliable spatial data on planting and management practices are not readily available. However, private and public sources of data are improving. Within the LTILRP itself, significant planting and management data are to be generated by the Farm Evaluations and Nitrogen Summary Reports. The Committee will coordinate closely with member coalitions to ensure these data are readily available and as useful as possible. Data interchange specifications will be developed to facilitate data quality and exchange. As these data become available, trends in implementation of protective practices can be characterized in greater detail and with greater accuracy. These characterizations will be combined with performance data to illustrate progress in protecting groundwater quality from degradation by irrigated agriculture. Results will be provided to coalitions for inclusion in annual reports, and included in MPEP deliverables, as appropriate.

3.13 REGULATORY DELIVERABLES

All regulatory deliverables will be prepared and submitted as required by the General Order. Regulatory deliverables related to the MPEP are identified in Table 1-1 and include the following:

- Management Practice Evaluation Workplan
- Addendums to the Workplan describing details of prioritized investigations
- Monitoring Well Installation and Sampling Plan

- Annual Reports
- Management Practices Evaluation Report

Other related deliverables include Management Plan Status Reports required for GQMPs. The Management Plan Status Reports will summarize progress in implementation of the management plans, including information about management practices. Management practice information from the MPEP will be available to coalitions for inclusion in GQMP deliverables.

4 SUMMARY CONCLUSIONS

The MPEP can, and by implementation of this Workplan will, achieve objectives listed in the General Order. The following are the objectives and a brief summary of how each will be attained. The approach was described in Section 2, and sections describing related, detailed activities are cited below.

1. ***Identify whether existing site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability groundwater areas.*** Current and evolving trends in practices will be tracked (Section 3.12). Efficacy of management practices will be assessed (Sections 3.6 and 3.8), extrapolated to the landscape (Section 3.10), and then related to groundwater quality (Section 3.9).
2. ***Determine if newly implemented management practices are improving or may result in improving groundwater quality.*** The process described for Objective 1 captures trends in practices, environmental performance, and groundwater quality through time.
3. ***Develop an estimate of the effect of Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive Officer or as a result of the recommendations by the expert panels by CDFA and the State Water Board, must be provided.*** The approaches described for Objective 1 are rigorous and robust in terms of mass balance, transport, storage, and transformations of nitrate, the focus of this phase of the MPEP. The same approach can be applied, when and if necessary, for other constituents of concern. The Committee is already working with Central Valley Water Board and CDFA staff, and with members of the expert panels, to develop and implement approaches and methodology. This collaboration will ensure quality and acceptability of the work.
4. ***Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.*** Sections 3.5 and 3.12 describe methods by which practices at member farms will be characterized. Section 3.10 explains how source evaluations (Sections 3.6 and 3.8) will be related to fields in which direct measurements are not necessarily conducted. In general, performance for these areas will be quantified as part of the landscape-level source quantification. Finally, outreach to boost rates of implementation where necessary (Section 3.11) and for identifying the extent of implementation (Section 3.12) are thoroughly described.

Other key MPEP elements, including vigorous and fruitful engagement of the Central Valley Water Board and broader agricultural, technical, and water quality communities, along with information and support to be exchanged with each, have also been described. Success in this daunting effort depends on the quality of collaboration and cooperation among these many parties, so the Committee is focused on fostering fruitful collaboration.

While much remains to be learned and developed, the MPEP is described in sufficient detail in this Workplan to allow (1) a relatively clear understanding of what is planned, (2) assessment of the Workplan sufficiency relative to MPEP objectives and requirements, (3) relatively detailed planning and budgeting for future activities, and (4) engagement of regulatory, technical, and funding partners to enable work to proceed.

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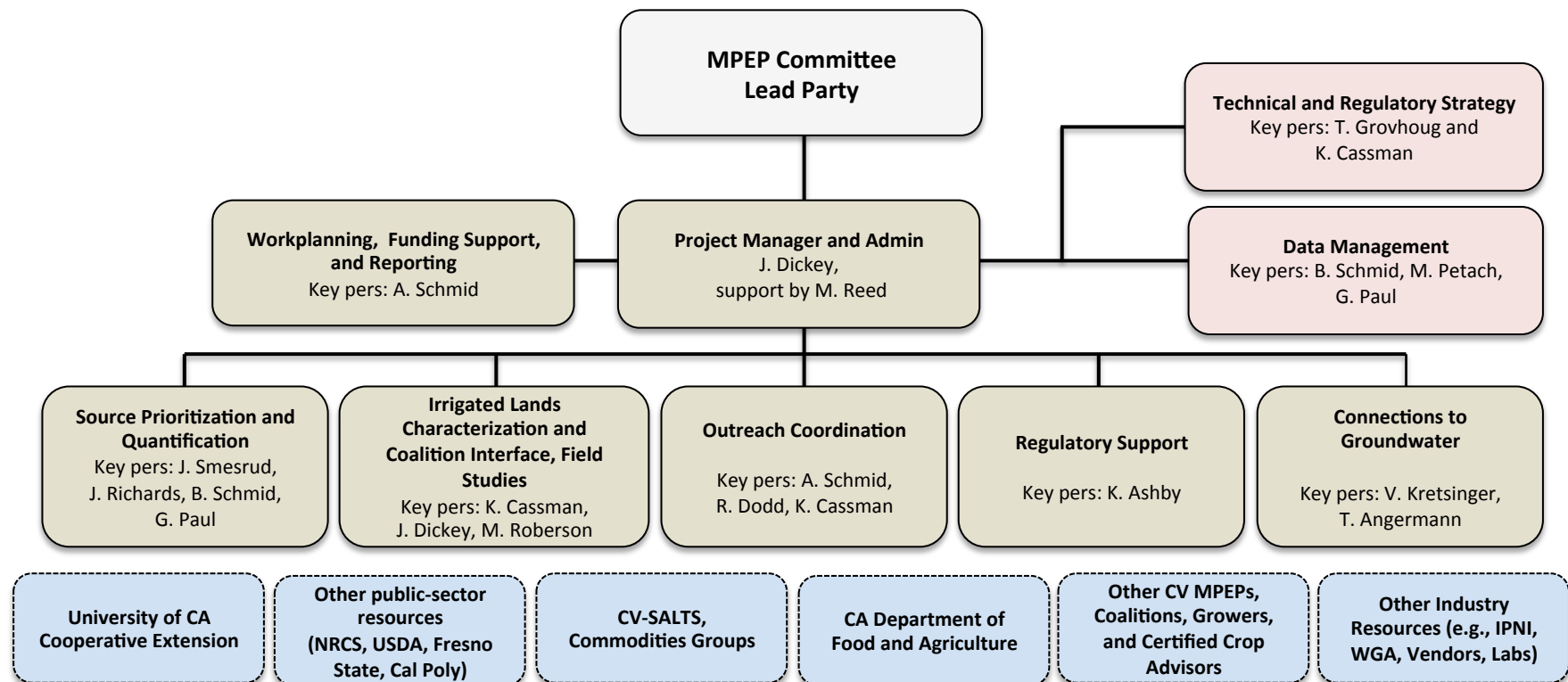
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APPENDIX A

ORGANIZATION CHART

PROJECT TEAM ORGANIZATIONAL CHART



Legend and Abbreviation

Key pers = Key personnel

Named Tasks

Components of "Technical MPEP Management and Oversight"

Potential Project Partners



September 2016

APPENDIX B

MPEP TEAM RESUMES

John B. Dickey, Ph.D., CPSS/Ag/CCA-CA

Principal Soil Scientist and Agronomist, Principal and Owner of PlanTierra LLC

611 Del Oro Pl., Davis, CA 95616; 530-554-9500; jdickey@plantierra.com; <http://www.plantierra.com/>

Education and Training: Ph.D., Soil Science, Purdue University, 1990; M.S., Agronomy, University of California, Davis, 1986; B.S., International Agricultural Development, University of California, Davis, 1979.

Professional Registrations: Certified Professional Soil Scientist and Crop Advisor (Agronomist, California) – American Registry of Certified Professionals in Agronomy, Crops and Soils (#03223)

Expert/Specialist in fate of salts, trace elements, and nutrients in surface and subsurface return flows; water and soil quality analyses for irrigation; analysis, reclamation, and revegetation of saline, sodic, and saline/sodic soils; regulatory (water and air quality) liaison and negotiations

Relevant Experience

Dr. Dickey is a Principal Soil Scientist and Agronomist with PlanTierra LLC, which he established in 2010 to work with agricultural, industrial, municipal, and environmental project partners on challenging land, vegetation, air, and water resources projects, mainly in California's Central Valley and Eastern Sierra. Dr. Dickey brings experience in environmental science consulting in the western United States, as well as in agricultural research, extension, production, and consulting in California, Indiana, Burkina Faso, and China.

- **Agricultural Crop Sensitivity and Salinity Management Strategies; CV-SALTS Lower San Joaquin River Committee; Stockton, California.** Identified key agricultural water quality policy questions. Reviewed report on agricultural water quality standards and recommended revisions. Helped to develop, describe, and analyze salinity management approaches. Supported irrigation districts in developing input to process.
- **Agricultural Support to Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS) Coalition, California.** Provider of technical support (analysis, interpretation) and strategic advice to members of the CV-SALTS Coalition, mainly on matters pertaining to salt and nitrate fate and management in and around irrigated lands, and on potential technical and regulatory approaches to these pollutants.
- **Initial Conceptual Model and Crop Sensitivity Zones; CV-SALTS; Sacramento, California.** For CV-SALTS (a stakeholder group seeking to develop tools for salinity and nitrogen management), helped develop input data and modeling for a pilot project (Tule River, Modesto, and Yolo areas), and 2 phases of Initial Conceptual Model (of salt, nitrogen, and water balances throughout the Central Valley), and developed a toolset for mapping crop sensitivity zones to inform narrative water quality standards to protect AGR [i.e., agricultural irrigation] beneficial uses). The zonal balances are fundamental to development of a Basin Plan Amendment for salt and nitrate, and for long-range regional planning for management of these water quality constituents.
- **Sonoma Valley Groundwater Subbasin and Santa Rosa Plain Salt & Nutrient Management Plans; City of Santa Rosa and Sonoma County Water Agency, California.** Two, separate, but similar projects. In collaboration with RMC Water & Environment (RMC), developed salt and nitrogen source geodatabase containing salt and nitrogen loading factors for over twenty land cover classes. Employed this tool to locate likely source concentrations to help focus watershed-level salt and nitrogen source control actions.
- **Development of Salt Loading for Drainage Management; U.S. Bureau of Reclamation (USBR) (San Luis Unit of the San Joaquin Valley) and Central Utah Conservancy District.** These projects involved developing quantitative subsurface drainage salt loading for regional drainage management.
- **Nitrogen Management to Protect Water Quality for various Central Valley Agricultural Clients.** Reviewed and commented on CDFA N tracking proposal and Nitrogen Management Planning Template for irrigated lands. Invited participant to the Nitrogen Management Plan Technical Advisory Work Group examining knowledge gaps with Central Valley Coalitions.
- **Water Quality Programs for the California Rice Commission (CRC).** Worked with CRC and the Water Board to develop an approved Monitoring and Reporting Program (MRP), developed to meet requirements of the Irrigated Lands Regulatory Program (ILRP). This work focused on influence of rice farming on surface water quality. This MRP was one of the first of its kind, structured to meet rice farmers' regulatory responsibilities, while complementing other regional water quality programs. As part of the Long-term ILRP (focused on

groundwater quality protection), again developed a technical approach based on an extensive regional water quality, soils, hydrographic, hydrogeologic, and land use database. Developed a conceptual model for loading, transport, and fate of applied irrigation water and nitrogen as part of a Groundwater Assessment Report to guide development of Waste Discharge Requirements, an associated MRP, and interpretation of collected data. Also supported CRC in their active participation in various other water quality processes (Central Valley Salinity Coalition [CV-Salts], The Delta Drinking Water Quality Technical Working Group, and the methyl-mercury TMDL. Author of Nitrogen Management Planning Template for rice production. Helped to design Farm Evaluation data structures and website.

- **Senior Consultant–National Institute for Agricultural Research and Study; Burkina Faso, West Africa.** Consulted the research team using aerial and satellite photography to evaluate soil conditions for plant growth and evolution of land surfaces (erosion and changes in cultivated and natural plant communities) in West African villages.
- **Lead Consultant–National Hog Farms (NHF); Kersey, Colorado (15,500 sows producing 349,000 pigs per year on 25,000 acres).** Worked with NHF on continuous improvement of nutrient management in their state-of-the-art, 2,900-acre land application system, the point of which was to recycle wastewater and nutrients without polluting underlying groundwater
- **Settlement Agreement; Cold Water Impacts to Rice in the Sacramento Valley, California.** For Richvale Irrigation District, and Biggs-West Gridley and Western Canal water districts, jointly negotiating with the California Department of Water Resources.
- **Settlement Agreement; Dust Control at Owens Lake, California.** For the Los Angeles Department of Water and Power, negotiating with Great Basin Unified Air Pollution Control District.
- **Expert Witness; Air Quality Impacts of a Water Transfer at Salton Sea, California.** For Imperial Irrigation District before the California State Water Resources Control Board.
- **Expert Witness; Nutrient Management Impacts on Air and Water Quality, Colorado.** For National Hog Farms before the Colorado Department of Public Health and the Environment, Divisions of Air and Water Quality.

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James Richards, Ph.D.

Specialist in Plant Ecophysiology, Plant Stress Physiology, and Plant-Soil Interactions

Education

Utah State University, Logan, UT, USA	Plant Physiological Ecology	Postdoc	1980-1982
University of Alberta, Edmonton, Canada	Botany-Plant Ecology	Ph.D.	1981
California Institute of Technology, Pasadena, CA, USA	Biology	B.S.	1970

Major Research Expertise

Plant physiological ecology, plant stress physiology, plant-soil interrelationships, plant adaptation to stressful environments, local adaptation and phenotypic plasticity of plants, application of plant physiological ecology and stress physiology to plant growth and restoration in severe environments

Appointments

2014 – Present	Professor Emeritus, Land, Air & Water Resources (LAWR), UC Davis, CA and Plant Ecophysiology, PlanTierra LLC, Davis, CA
1995 – 2014	Professor, LAWR, UC Davis, CA
2003 – 2007	Vice Chair, Soils and Biogeochemistry Section, LAWR, UC Davis, CA
1993 – 1995	Associate Professor, LAWR, UC Davis, CA
1990 – 1993	Assistant Professor, LAWR, UC Davis, CA
1985	Senior Visiting Scientist, CSIRO, Cunningham Lab, Brisbane, Australia
1987 – 1990	Associate Professor, Range Science, Utah State Univ., Logan, UT
1982 – 1987	Assistant Professor, Range Science, Utah State Univ., Logan, UT

Relevant Experience

Dr. Richards has conducted basic and applied research on the interaction of plant root systems and vadose zone hydrology in desert, semi-arid, and riparian systems since 1981. This research established the basis for understanding: hydraulic redistribution by plant root systems, interactions of roots and soil affecting nutrient acquisition, and the plant physiological basis for limits of tolerance of salinity, boron toxicity, water stress, seed production and dispersal, and seedling growth and establishment in stressful semi-arid and arid environments. The basic research results documented in more than 125 peer-reviewed publications have been applied in conservation, restoration and dust control projects.

Selected Publications (total peer-reviewed: >125)

Lovell JT, Mullen JL, Lowry DB, Awole K, Richards JH, Sen S, Verslues PE, Juenger TE, McKay JK 2015. Exploiting differential gene expression and epistasis to discover candidate genes for drought-associated QTLs in *Arabidopsis thaliana*. **Plant Cell**. *In press*. [doi:10.1105/tpc.15.00122]

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- James JJ, Richards JH. 2006. Plant nitrogen capture in pulse-driven systems: interactions between root responses and soil processes. **Journal of Ecology** 94: 765-777.
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- James JJ, Tiller RL, Richards JH. 2005. Multiple resources limit plant growth and function in a saline-alkaline desert community. **Journal of Ecology** 93: 113-126.

Andrea Schmid, M.S.

Specialist in Environmental Planning and Regulatory Compliance

Education

M.S., Natural Resource Ecology and Management/Journalism and Communications, Iowa State University

B.S., Horticulture, Iowa State University

Relevant Experience

Ms. Schmid has ten years of experience in environmental planning, permitting, regulatory compliance, and stakeholder outreach. She is experienced in multi-stakeholder settings and works closely with clients, regulators, and consulting teams to develop reasonable and cost-effective approaches to a variety of natural resource issues. Her expertise includes regulatory support, concise environmental documentation, and water resources planning. She has worked extensively on projects focused on water resources, the Clean Air Act, the Clean Water Act, and the Endangered Species Act. As a Soil Conservationist, Ms. Schmid has also provided technical assistance to landowners with the development and implementation of conservation practices and programs.

Representative Project Experience

Owens Lake Dust Mitigation Program; Los Angeles Department of Water and Power; Owens Lake, California.

The Owens Lake bed covers approximately 110 square miles in the southern end of the Owens Valley. Historically, Owens Lake received surface water inflow from the Owens River and the Sierra Nevada. As a result of water diversions beginning in the 1860s, inflow was significantly reduced and the lake was virtually dry by 1930. Prior to implementation of dust control measures, the dry lake bed was the major source of dust in Owens Valley and one of the largest sources of dust in the world. Since 2001, over 40 square miles of dust control have been implemented, controlling almost 90 percent of the dust. Ms. Schmid has provided support to the Owens Lake Dust Mitigation Program since 2009. Specific efforts include the following:

- Ms. Schmid was the lead planner for development of a plan to provide long-range management of the 110 square-mile Owens Lake playa in Inyo County, California. The playa provides diverse resources, but it is also a major source of fugitive dust emissions due to water diversions. The plan provides a framework to control dust, conserve water, and maintain habitat value, while also protecting other lake resources. Key issues for this plan include: diverse stakeholders, water conservation, fugitive dust control, wildlife habitat, cultural resources, and public outreach.
- Preparation of numerous technical documents related to research and development of waterless and water-efficient dust control measures; research and development of new monitoring technologies; and regulatory compliance documents required by the air district. Also assisted with preparation of the LADWP Investigation into the Origin and Development of the Modern Keeler Dunes.

Imperial Irrigation District, Water Conservation and Transfer Project; Imperial Valley, California. The Salton Sea is the largest inland lake in California, totaling more than 375 square miles in Imperial and Riverside counties. The Water Conservation and Transfer Project includes a long-term transfer of up to 303,000 acre-feet of water annually from IID to the San Diego County Water Authority, Coachella Valley Water District, and Metropolitan Water District of Southern California. The Water Transfer Project, along with other factors affecting Salton Sea inflows and water balance, will result in reduced Sea elevations, Sea floor exposure, and decreased water quality due to rising salinity and selenium. After 2017, mitigation flows to the Sea to offset the impact of water transfers will cease, causing a significant increase in exposed playa. Ms. Schmid has provided support on air quality and habitat issues at the Sea since 2007. Specific efforts include the following:

- Assisted with the air quality analyses for the Supplemental EIR/EIS for the Water Conservation and Transfer Project. Air quality impacts included construction and operation of on-farm and delivery system conservation measures, construction and operation of HCP/NCCP Measures, windblown dust from fallowed farmland, windblown dust from Salton Sea playa, and emissions from engines associated with on-farm water conservation measures.
- Assisted in development of the Air Quality Mitigation Program, which includes development and implementation of a robust, science-based, pro-active, and adaptive air quality plan to detect, locate, assess and mitigate potential PM10 emissions associated with the Water Transfer Project.
- Prepared several technical documents including evaluation of the air district's proposed rule to mitigate dust emissions from the sea and research and development of dust control measures

Other Experience. Ms. Schmid's experience also includes the following:

- *Funding Opportunities.* Prepared grant applications on behalf of clients, including applications to the Bechtel Foundation and the California Wildlife Conservation Board. Secured a \$250,000 grant from the Bechtel Foundation for a data management and collaboration project in the Sacramento-San Joaquin Delta.
- *Public Outreach Materials.* Prepared articulate public outreach materials, including press releases, project brochures, and political briefing materials. Provided technical briefings to a variety of elected officials in Washington, D.C.
- *State and Federal Permitting.* Led environmental permitting for the Fish Passage Improvement Project at Red Bluff Diversion Dam on the northern Sacramento River. Permits included state and federal Endangered Species Act compliance, US Army Corps of Engineers, CDFW, RWQCB, and various local permits for both the long-term and interim pumping facilities. All environmental permits were obtained on time. She also managed development of the 32-acre Habitat Mitigation and Monitoring Plan. The mitigation site recently completed construction and is in the maintenance and monitoring phase.

Thomas R. Grovhoug, President

Education

M.S., Civil
Engineering, 1975,
University of
California, Davis

B.S., Civil
Engineering, 1973,
University of
California, Davis

Years of Experience

39

Registration

Civil Engineering,
State of California,
No. 27901

Professional

Affiliations

Member, Water
Environment
Federation

Member, California
Water Environment
Association

Associate Member,
California
Association of
Sanitation Agencies

Member, Northern
California Society of
Environmental
Toxicologists and
Chemists

Member, Wadeable
Streams Nutrient
Policy Stakeholder
Advisory Committee

As the President of LWA, Mr. Grovhoug is responsible for the leadership of the company and the overall quality of technical work performed by the firm. His work for numerous municipal clients over the past 32 years at LWA has focused on water quality issues: monitoring, modeling, permitting, and policy development. In his frequent role as either a project manager or project advisor, he is responsible for project team leadership and management, budgeting, scheduling, regulatory agency communications, public presentations, and product quality.

Mr. Grovhoug's specific area of expertise includes collaborative policy development and water quality management working with regulators, municipal, agricultural and non-governmental organizations on a variety of topics, including salinity and nitrate in surface and ground waters of the Central Valley, nutrients in surface waters of the Sacramento-San Joaquin Delta, San Francisco Bay and Wadeable streams of California, mercury in the Delta, and others. Mr. Grovhoug has extensive experience in the development of water quality objectives, Basin Plan amendments, anti-degradation analysis, and offset and trading programs in California. He has played a key role in numerous CV-SALTS projects, including the development of salinity objectives in the Lower San Joaquin River, the development of a Central Valley Salt and Nitrate Management Plan, and the development of a groundwater management zone archetype study in the Alta Irrigation District study area.

Mr. Grovhoug is an expert in Clean Water Act and California Water Code regulatory issues, over the past three decades, with extensive experience pertaining to NPDES discharge permits and TMDLs in California. He has provided a broad range of technical and regulatory policy analysis as a consultant to the Sacramento Regional County Sanitation District, Central Valley Clean Water Association and Bay Area Clean Water Agencies over the past 20 years

RECENT EXPERIENCE AT LARRY WALKER ASSOCIATES

San Joaquin Valley Drainage Authority, CV-SALTS Initial Conceptual Model and Central Valley Salt and Nitrate Management Plan development (2015)

East Stanislaus Resource Conservation District, Development of Salinity Objectives for Lower San Joaquin River, CV-SALTS Lower San Joaquin River Committee (2015)

Central Valley Clean Water Association, Development of Variance Authority and Streamlined Salinity Variance for the Central Valley (2013)

Central Valley Clean Water Association, Development of White Papers to address NPDES permitting issues in the Central Valley, including Whole Effluent Toxicity, anti-degradation, receiving water monitoring, and mixing zones.(2012)

Sacramento Regional County Sanitation District, Participation in work group for development of Delta Drinking Water Policy (2013)

Bay Area Clean Water Agencies, Development of Regulatory Strategy to support implementation of a Nutrient Management Strategy for San Francisco Bay (2013)

Central Valley Clean Water Association, Development of comments on Delta Plan and Bay Delta Conservation Plan (2013)

Bay Area Clean Water Agencies, Review and analysis of Whole Effluent Toxicity Policy proposed by State Water Resources Control Board (2011)

Thomas R. Grovhoug, President

Sacramento Regional County Sanitation District, NPDES Permit renewal studies and policy support(2015)

Sacramento Regional County Sanitation District, Study of the Local Bioaccumulative effects of mercury in treated effluent discharge to the Sacramento River near Freeport (2008)

Sacramento Regional County Sanitation District, Feasibility Study for Mercury Offsets in the Sacramento River Watershed (2005)

Bay Area Clean Water Agencies, Cyanide Site-specific water quality objective and Shallow Water Discharger Implementation Plan, Technical support to Regional Water Quality Control Board in development of Basin Plan amendment (2005)

Clean Estuary Partnership, Site-specific Water Quality Objectives for Copper and Nickel for San Francisco Bay north of the Dumbarton Bridge (2004)

Education

B.S., Biological Sciences, 1991, University of California, Irvine

Years of Experience
23

Certifications

Certified Professional in Storm Water Quality, 2004, CPESC, Inc. #0081

Hazardous Materials Management Certificate, 1997, University of California, Irvine

Professional Affiliations

Chair, CASQA, Jan 2004 – Dec 2005

Vice Chair, CASQA, Nov 2001 – Dec 2003

Board of Director September 2002 – Dec 2008

Member, CASQA, 1999 - Present

Ms. Ashby is a Vice President and serves as a Project Manager for LWA's work in the stormwater and watershed management fields. She has over 20 years of experience in the development, implementation, and assessment of watershed and stormwater management programs (Phase I and Phase II) as well as a number of watershed-specific studies and Total Maximum Daily Loads (TMDLs). She has been responsible for facilitating permit renewals, reviewing and commenting on numerous policies, guidance materials and permits, developing and implementing watershed and stormwater management programs and TMDLs, developing program effectiveness assessment strategies and evaluating the effectiveness of stormwater programs, developing program cost analyses for various funding initiatives, developing and providing stormwater-related adult learning-based training modules, and preparing various technical reports. She has also played a key role in numerous CV-SALTS projects, including the development of salinity objectives in the Lower San Joaquin River, the development of a Central Valley Salt and Nitrate Management Plan, and the development of a groundwater management zone archetype study in the Alta Irrigation District study area.

Representative projects include the following.

RELEVANT EXPERIENCE AT LARRY WALKER ASSOCIATES

Watershed Management/TMDLs

Central Valley Salinity Coalition – Development of a Basin Plan Amendment for Salt and Boron in the Lower San Joaquin River

Consultant Team Project Manager to guide the development of a Basin Plan Amendment (BPA) for salt and boron in the Lower San Joaquin River (LSJR). Ms. Ashby is working with multiple stakeholders and regulatory and partner agencies and overseeing the technical and regulatory work, which includes defining the beneficial uses of the LSJR, evaluating the range of potential water quality objectives (WQOs), proposing WQOs for salinity and boron that are protective of the most sensitive use(s), and evaluating (through modeling) the range of implementation mechanisms that may be necessary to ensure the objectives are met. The technical work from this project will provide the basis for a subsequent BPA to the Water Quality Control Plan (Basin Plan) for the Sacramento/San Joaquin Basin.

Central Valley Salinity Coalition – Evaluation of Municipal and Domestic Beneficial Uses of Groundwater in the Tulare Lakebed and Development of a Basin Plan Amendment

Consultant Team Project Manager to guide the development of a Basin Plan Amendment (BPA) for a proposed de-designation of the MUN beneficial use in groundwater for a portion of the Tulare Lakebed. Ms. Ashby is working with multiple stakeholders and regulatory and partner agencies and overseeing the technical and regulatory work, which includes defining the problem statement, proposing regulatory alternatives, developing the substitute environmental document (SED) to address the potential environmental impacts of the project, conducting the economic analysis, and assisting with the development of the staff report. The work from this project will provide the basis for a subsequent BPA to the Water Quality Control Plan (Basin Plan) for the Tulare Lake Basin.

Central Valley Salinity Coalition – Development of a Preliminary Draft Central Valley-

Wide Salt and Nitrate Management Plan (Project Phase II)

Consultant Team Project Manager for the development of a Preliminary Draft Central Valley-wide Salt and Nitrate Management Plan (SNMP). Consistent with the overarching goals of CV-SALTS and the Recycled Water Policy for the State of California, Ms. Ashby is overseeing the development of a comprehensive SNMP and working with multiple stakeholders and regulatory and partner agencies to identify the approach and establish the basis for the short- and long-term management of salt and nitrate in the Central Valley region. The knowledge base, technical analyses, and associated documentation developed as part of the SNMP will form the basis for corresponding Basin Plan Amendments (BPAs) to the Water Quality Control Plans (Basin Plans) for the Sacramento/San Joaquin Basin and Tulare Lake Basin. The technical work developed as a part of this project will also provide information to support more detailed, sub-regional analyses that may be undertaken in the future by local stakeholder groups if they choose to develop local SNMPs .

Central Valley Salinity Coalition – Development of an Initial Conceptual Model for a Central Valley-Wide Salt and Nitrate Management Plan (Project Phase I)

Consultant Team Project Manager for the development of an initial conceptual model (ICM) for a Central Valley-wide Salt and Nitrate Management Plan (SNMP) as well as geographic information systems (GIS) technical services.

The ICM, which was developed in a collaborative setting with multiple stakeholders and regulatory and partner agencies, is the first phase of work that needs to be completed to fully develop the Central Valley SNMP. The work effort included obtaining surface water and groundwater data throughout the valley and/or Region 5 jurisdiction, establishing zones throughout the valley floor for the analyses, establishing methods for the salt and nitrate water quality analyses, performing the high-level analysis of salt and nitrate conditions throughout the valley floor, and preparing a report with the findings of the analyses and recommendations for the development of the final Central Valley SNMP.

Additional work included GIS technical services to continue to organize information pertaining to the beneficial uses, water quality objectives, and water quality of surface and groundwater in the Central Valley. This work also included the development of crop sensitivity tools for irrigated lands in the Central Valley.

County of Orange - Nitrogen and Selenium Management Program

Project Manager (2004-2009) and Strategic Advisor (2013 – present) for the Nitrogen and Selenium Management Program in Orange County which includes the development of nitrogen and selenium conceptual models, sources and loads evaluations, treatment Best Management Practice evaluation and modeling, development of a selenium site-specific objective as well as the feasibility and development of trading/offset programs for selenium and nitrogen for short- and long-term dewatering discharges.

Additional work included the development of a collaborative selenium TMDL which required assistance with the existing sources and loads and loading capacity, development of the waste load and load allocations, implementation plan, environmental analysis and documentation (CEQA), incorporation of the numeric targets and secondary water column guidelines. Additional work also included review of the impairment assessment, economic analysis, linkage analysis, and facilitation with the watershed stakeholder group and regulatory agencies

Current Role

Principal Hydrogeologist at Luhdorff & Scalmanini Consulting Engineers

Education

Master of Science - Hydrologic Sciences, University of California, Davis, CA

Bachelor of Science - Geology, Freie Universität, Berlin, Germany

Professional Summary

Fifteen years of professional experience and expertise includes:

- ❑ conceptualization of hydrogeologic systems
- ❑ scientific method and experimental design
- ❑ data quality objectives, sampling protocols, measurement
- ❑ quantitative analysis
- ❑ groundwater hydraulic, hydrologic, hydrogeologic, and hydrochemical assessment
- ❑ micrometeorology
- ❑ parametric and nonparametric statistical analysis, uncertainty analysis, censored data
- ❑ surface water/groundwater interactions
- ❑ infiltration and runoff processes, deep percolation and groundwater recharge
- ❑ non-point source agricultural subsurface mass emissions of nutrients and minerals

Since 2008, Mr. Angermann has been providing vision and groundwater-related technical services to the Central Valley dairy community including Dairy Cares, Western United Dairymen, the Central Valley Dairy Representative Monitoring Program, and individual dairymen.

Project Experience

Dairy Cares

An early key accomplishment was the conceptualization of a Representative Monitoring Program (RMP) in response to the 2007 Dairy General Order. The Regional Board's modus operandi required groundwater conditions assessment on all existing dairy farms (over 1,400 at the time) which would have meant the installation of possibly upwards of 10,000 dedicated monitoring wells. The RMP replaced this approach with a comprehensive and cohesive data collection effort on 42 dairies that are representative of the industry and the range of pertinent site conditions. The Regional Board's approval of the RMP marked a regulatory paradigm shift in the context of agricultural non-point source subsurface mass emissions.

Western United Dairymen

Lead technical expert to Western United Dairymen for the testing and implementation of a water balance method using high-precision instrumentation and a mechanistic bulk-aerodynamic transfer model to determine seepage rates of working liquid dairy manure storage lagoons with quantified uncertainty. Preparation of a Technical Field Guide in 2012.

Central Valley Dairy Representative Monitoring Program (CVDRMP)

Technical Program Manager since its inception in 2010

Under his leadership, CVDRMP established a track record of steady progress supported by systematic, science-based efforts toward the development of evidence-based industry recommendations in accordance with the schedule set forth in the Dairy General Order. Responsibilities and achievements include:

- ❑ Assembling, coordinating and leading two external technical advisory committees – these committees have been critical for the vetting of CVDRMP activities. Committees are composed of researchers and other experts from the University of California, Lawrence Livermore National Laboratory, U.S. Geological Survey, California Department of Food and Agriculture (CDFA), the agricultural, private, and non-profit sectors.
- ❑ Management of all aspects of what is believed to be the largest industry-specific monitoring well network of its kind in California.
- ❑ Development and implementation of special studies that far exceed requirements of the General Order, such as
 - Liquid dairy manure lagoon seepage testing using the water balance method (completed).
 - Lagoon perimeter subsurface hydrogeologic investigations and geophysical surveys to investigate the extent of seepage impacts to groundwater (ongoing).
 - Investigation of unsaturated zone travel times and groundwater ages using environmental tracers, isotopic, and noble gas analysis (2015).
- ❑ Technical briefings at the Governor's office and to top administrators at CDFA and California's Environmental Protection Agency. Presentations to the State Water Board, Regional Water Board, and stakeholder groups.

Agricultural Panel of Experts

Served among eight experts. This Panel was convened in May 2014 by the State Water Board in the context of Chapter 1 of the Second Extraordinary Session of 2008 (SBX2 1, Perata) to assess existing agricultural nitrate control programs and develop recommendations, as needed, to ensure that ongoing efforts are protective of groundwater quality. The final report was presented to the State Water Board in September 2014.

Journal Article Contributions

Zalom, F. G., M. N. Oliver, W. W. Wallender, I. Werner, B. W. Wilson, W. H. Krueger, **T. Angermann**, L. A. Deanovic, T. S. Kimball, J. D. Henderson, G. H. Oliveira, and P. Osterli. **2002.** *Monitoring and mitigating offsite movement of dormant spray pesticides from California orchards.* Acta Horticulturae 592:729-735

Angermann, T.E., Wallender, W.W., Wilson, B.W., Werner, I., Hinton, D.E., Oliver, M.N., Zalom, F.G., Henderson, J.D., Oliveira, G.H., Deanovic, L.A., Osterli, P., Krueger, W. **2002.** *Runoff from orchard floors – micro-plot field experiments and modeling.* Journal of Hydrology 265: 178-194.

Joyce, B.A., Wallender, W.W., **Angermann, T.E.**, Wilson, B.W., Werner, I., Oliver, M.N., Zalom, F.G., Henderson, J.D. **2004.** *Using Infiltration Enhancement and Soil Water Management to Reduce Diazinon in Runoff.* Journal of the American Water Resources Association 40(4): 1063-1070

Current Role

President and Senior Principal Hydrologist at Luhdorff & Scalmanini Consulting Engineers

Education

Master of Science - Water Science, University of California, Davis, CA

Bachelor of Science - Environmental Toxicology, University of California, Davis, CA

Professional Summary

Ms. Kretsinger Grabert has more than 30 years of experience in groundwater quality assessment and resource management, including design of monitoring networks and programs, application of environmental regulations, long-term groundwater quality monitoring and protection programs, and groundwater supply sufficiency and availability assessments and technical assistance for projects involving litigation. She has managed county and basin-wide groundwater monitoring programs and characterization of groundwater conditions, including development of sampling, monitoring and analytical protocol, and quality control/quality assurance programs. Ms. Kretsinger Grabert specializes in the understanding of contaminant transport and fate in hydrologic systems and the potential implication of the presence of natural or man-made contaminants.

She has a long history of working on groundwater conditions, especially groundwater quality, on local and regional scales. She guides the technical team at the outset of projects in the identification of approaches that meet each individual client's needs with special consideration of their unique hydrogeologic setting and applicable regulatory requirements. Ms. Kretsinger Grabert has a demonstrated ability to work with groups containing diverse interests in order to identify and receive approval for acceptable solutions to complex issues. Ms. Kretsinger Grabert has managed complex projects and has led the way with forward-thinking and sound scientific approaches.

Project Experience**CV-SALTS Salt and Nitrate Management Plan**

She has been involved in CV-SALTS projects as a contractor and also a volunteer since 2009. She has strong team management and project management skills, and her understanding of the long-term goals of sustainability that drives CV-SALTS actions for managing salt and nitrate in the Central Valley's water bodies above and below ground. She managed LSCE's technical work as part of the LWA team that designed and implemented the Salt and Nitrate Sources Pilot Implementation Study, which involved three study areas and groundwater flow and transport evaluations in the Yolo, Modesto and Tulare regions. She managed the groundwater work for the Initial Conceptual Model (ICM, Salt and Nitrate Management Plan Phase I). As part of this work, LSCE developed the first-ever analysis of surface water and groundwater quantity and quality (salt and nitrate) over a time period of 20 years that was used to evaluate surface water and groundwater effects from changes in mass loading (from surface applications or contributions from stream leakage) in the entire Central Valley. The Phase I work also involved the development of a groundwater flow and transport model in the Kings Subbasin area, which was one of two prototypes. LSCE is now part of the LWA team developing the Preliminary Draft of the Central Valley Salt and Nitrate Management Plan (CV-SNMP). The latter work includes development of a groundwater flow and transport model for the archetype in the Alta Irrigation District (AID) area; this is being done in coordination with Kings River Conservation District (KRCD) and AID.

She has provided numerous presentations to the CV-SALTS Policy and Executive Committees and the Technical Advisory and Project Committees. She has attended many CV-SALTS Policy meetings as an

interested person (most of the time, her attendance has been as a volunteer and not part of budgeted work). She felt it was critical to hear the dialog, including suggestions and concerns, expressed during policy-related discussions and to offer technical input when such input was important to the attendees' understanding of the linkages between policy decisions and science.

Irrigated Lands Regulatory Program with Emphasis on Groundwater Requirements

She has managed LSCE's work on the preparation of Groundwater Quality Assessment Reports (GARs) for three agricultural water quality coalitions in the Central Valley (East San Joaquin Water Quality Coalition, Westlands Water Quality Coalition, and Westside San Joaquin River Watershed Coalition; all GARs are completed) and is currently working on groundwater quality characterization reports for the Central Coast North and South Counties areas for another coalition. All work during the preparation of the GARs involved close coordination with the Regional Water Board staff. During preparation of the ESJWQC GAR, coordination with the Regional Board, stakeholder groups, and representatives of other coalitions was particularly important due to the novelty of the GAR process and the implications for the agricultural coalitions. Ms. Kretsinger Grabert has provided presentations to the Regional Water Board and the State Water Board during the preparation of the ESJWQC GAR. That GAR was approved on December 24, 2014, and LSCE is now preparing the Groundwater Quality Trend Monitoring Workplan. She has served as senior technical advisor for the Central Valley Dairy Representative Monitoring Program. LSCE is also part of a team (along with KRCD and others) selected for a California Department of Food and Agriculture Specialty Crop Block Grant. The focus of this project is evaluation of nitrate leaching risk from specialty crop fields during on-farm managed floodwater recharge in the Kings Subbasin.

Countywide Monitoring Programs and Technical Support

She has managed groundwater management plans and/or water supply assessments for cities and/or water purveyors. She has worked with the Napa County Groundwater Resources Advisory Committee for two and a half years (every other month workshops) to educate the Committee on the County's groundwater resources and to aid County staff and the Committee in community outreach and education efforts, particularly as related to volunteered participation in the countywide groundwater monitoring program designed by LSCE. She is the project manager for a DWR grant awarded to the County for the installation of groundwater and surface water monitoring facilities along the Napa River to investigate stream and aquifer connectivity. She led technical support provided to the County to update its water availability analysis policy document for discretionary groundwater projects. The updated draft policy document includes analysis of potential mutual well interference and streamflow depletion related to pumping (where applicable). This policy document was recently approved by the Napa County Planning Commission with no objections from the public and is scheduled to be heard by the County Board of Supervisors in May. The Planning Commission commended County staff and LSCE for the transparency of the process and working together with the agricultural community (vintners and grape growers associations and the County Farm Bureau), environmental organizations and the public.

Volunteer Activities (examples)

She is the Founding President of the Groundwater Resources Association of California (GRA) and a member of the Board of Directors from 1992-2014. In 2010, she planned and organized the launch of a new Contemporary Groundwater Issues Council on behalf of GRA. The Council consists of nearly three dozen local, state, national distinguished executives and leaders (including KRCD) who are providing their input on the most pressing information, education, and conference and training program needs to address California's groundwater challenges. She is co-organizing the 2015 Council Workshop which will focus on the implementation of the Sustainable Groundwater Management Act implementation, particularly input on key issues and concerns from Council members. She co-led the Groundwater Caucus for the Department of Water Resources California Water Plan Update 2013.

Brian M. Schmid, M.S., CPSS
Senior Quantitative Agronomist/Soil Scientist/Remote Sensing Specialist

Education: M.S. Soil Science 2005 Iowa State University

B.S. Agronomy 2002 Iowa State University

Brian Schmid is a senior quantitative soil scientist/agronomist with Formation Environmental, LLC. Over the last 12 years, Brian has specialized in developing and applying advanced technologies (remote sensing, GIS, and agronomic crop modeling) to accurately map, describe, predict, and report land surface conditions pertaining to agricultural production, precision agriculture, soil remediation, regulatory support, and environmental objectives. Specifically, Brian combines advanced soil and agronomic crop modeling tools with remotely sensed data to simulate crop growth, yield, and nutrient / water movement as a function of the soil-plant-atmosphere-management dynamics. In addition, Brian has used these site specific and regional simulations to assess impacts of irrigation management, nutrient management, and climate change on production as well as environmental and regulatory implications. Brian has significant project experience in the Central Valley of California, including: detailed crop mapping, crop identification, crop management, agronomic modeling, water quality assessment, and nitrate management using remote sensing and GIS techniques.

Brian has led the development of several large scale agricultural remote sensing assessments; including the development of a remote sensing technique to identify marijuana grow locations, characteristics, and their impact on resources downstream. Brian has also developed advanced remote sensing techniques to quantify rice yield and yield loss due to irrigation with cold water. This remote sensing technique allows for accurate quantification of rice yield loss on over 150,000 acres. The results are used to justify crop damages and thus payment for yield loss to growers in five water districts affected by the cold water released from a nearby dam. In addition, Brian is currently involved in a large effort to spatially map daily evapotranspiration using satellite imagery (at 30 meter resolution) for the entire state of California. Data will be available on a weekly basis for 2000 to present.

Brian is the lead scientist developing in-season nitrogen management tools for rice growers within Butte County. Combining remote sensing techniques and field data, the procedure quantifies leaf tissue nitrogen on a weekly basis with satellite imagery. Growers use this information to determine top-dress nitrogen rates to optimize yield and plant health.

In addition to his experience in the Central Valley, Brian serves as project manager and technical lead on numerous projects throughout the mid- and western United States, most notably on the Imperial Irrigation District (IID) Air Quality Mitigation Program, Green Acres Farm Nutrient Management Project, and the IID Se Fate/Transport Project. Prior to joining Formation Environmental, Brian managed the Soil and Landscape Analysis Laboratory at Iowa State University where he developed several techniques for combining remotely sensed data sources, GIS, and geostatistics to model soil properties and thus soil management units on the landscape.

As a member of his family's farming operation, Brian continues an active agronomic support role in their large grain and livestock operation in northwest Iowa.

Representative Project Experience

Marijuana Grow Identification and Evaluation; Confidential Clients (2013 to present)

Since 2013, Brian has been the lead scientist in the development of customized, proprietary, remote sensing methods for identifying marijuana grows locations and footprints in Northern California. This proven approach has been implemented on over 5,000 square kilometers in Northern California, representing

diverse watersheds, habitats, ecosystems, soils, and topography. Our clients' independent accuracy assessments confirm overall map accuracies greater than 95 percent. Our approach facilitates time series analysis, providing temporal data on yearly marijuana cultivation and production from 2005 to present on a watershed basis.

In order to help our clients prioritize limited resources (e.g., funding, staff, outreach, budgets), Brian developed innovative methods for estimating important grow characteristics related to water use and environmental risk. Specifically, this includes quantifying plant population per grow, and estimating water and nitrogen use on a seasonal basis. This foundational information allows our clients to focus their resources and activities on grows that impact humans, soils, streams, habitat, and fisheries. For example, one of our clients used this data to calculate a sub-watershed scale water balance. The water balance was used to identify timeframes when local streams would be most impacted by upstream diversions.

Cold Water Rice Evaluation; Department of Water Resources & Butte County Water Districts; (2005 to present)

Since 2005, Brian has been the Lead Scientist for developing innovative methods to quantify rice yield loss due to irrigation with cold water on approximately 150,000 acres in the Sacramento Valley. Rice yield is reduced near field inlets by the delivery of cold water from a nearby dam. Brian led the development of an accurate remote sensing approach that utilizes data logs from producers' yield monitoring harvesters to calibrate aerial and satellite imagery by employing state-of-the-art statistical and remote sensing methods. The resulting yield maps are accurate (less than 4% error), show detailed variations in yield, and can be used to establish the basis for compensation from yield damage caused by cold water. Alternative methods to the remote sensing approach have also been developed and are being systematically compared to an independent dataset for accuracy, cost efficiency, and ultimately equitability of payment distribution to affected growers. Brian participated and presented results on a monthly basis to a Technical Panel composed of the Department of Water Resources and 5 Butte County Water Districts.

Nitrogen Management Toolset; Butte County Rice Growers Association (2011 to present)

Since 2011, Brian has been the Lead Scientist for developing innovative methods to quantify leaf nitrogen in rice crops using satellite imagery and advanced plant canopy models. The advanced remote sensing method allows quantification of biomass and leaf tissue nitrogen dynamically from satellite imagery. Rice growers within the BUCRA service area are using this information throughout the growing season to make management recommendations and adjustments to irrigation and nitrogen applications (top dress). Beginning in 2014, the method is being expanded to tomatoes within the Central Valley and potatoes in Idaho.

Statewide Evapotranspiration Monitoring System; Confidential Clients (2015 to present)

Since 2015, Brian has been working with a multi-disciplinary team developing a comprehensive framework for spatially mapping Daily Actual Evapotranspiration (ETa) for the entire state of California using publically available satellite data imagery. The core of the framework is comprised of historic satellite imagery (1985 to present), weather data, and surface energy balance algorithms. The framework has the capability of generating daily ET maps using the Surface Energy Balance System (SEBS) or the Two Source Model (TSM) for the entire State from 30m to 250m spatial resolution. This data is being used by our clients to manage water resources, hydrologic modeling activities, water planning, drought planning, and crop management.

George Paul, PhD
Senior Agronomist / Remote Sensing Analyst / Ag. Engineer

Education: B.S Agricultural Engineering 2002, AAI, India
M.S. Civil Engineering (Water Resources) 2004, MNNIT, India
Ph.D. Agronomy (Ag. Systems Modeling) 2013, Kansas State University

Dr. George Paul is a Senior Agronomist/Agricultural Engineer with Formation Environmental, LLC. George is a biophysically-oriented systems scientist. George has extensive educational and professional experience in field measurements including remote sensing / numerical modeling of soil, plant, and hydrologic processes. George has 10 years of experience focused on modeling spatio-temporal aspects of soil-water-plant-environment processes and their interactions with changing climate using remotely sensed data. He has been the lead scientist on projects involving irrigation performance, remote sensing, crop modeling, soil heat flux, soil-water conservation, rainfall-runoff modeling, evapotranspiration (ET) modeling, spatial biophysical modeling, climate change impact-adaptation modeling, and drought-flood studies. George has extensive experience in analyzing big data including weather, soil, satellite and surface flux datasets for managing and supporting agricultural operations. He has developed research programs within the arena of agriculture systems dynamics/resilience with focus on sustainable production especially for regions with limited water resources. George has served in various capacities, including organizing symposiums, moderating sessions, reviewing papers and proposals, developing proposals, producing reports & publications, serving on committees, serving actively in professional societies, nominating peers, and advising students.

George is an expert in evapotranspiration (ET) research from remotely sensed imagery. He has proficiency in the various ET measurement techniques which includes eddy correlation, Bowen ratio energy balance, lysimetry, surface renewal, water balance, sap flow, scintillometry, remote sensing-based algorithms, and direct modeling. He has evaluated and incorporated improvements to major remote sensing based surface energy balance algorithms including SEBAL, METRIC, SEBS, and TSM. In a recently concluded work, he has developed a computing framework to generate daily ET maps from satellite data (Landsat TM and MODIS) for the state of Oklahoma, Texas and Kansas. The final output was 20 TB of data (ET, Transpiration and Evaporation) which is being used for ground water management, hydrological modeling, agricultural water management, ecosystems modeling and climate studies. Dr. Paul's research efforts involve sensor-assisted irrigation, development of better crop coefficients, remote sensing based ET mapping, deficit water management practices, development of ET network, and demonstration projects for disseminating state-of-the-art technologies to producers. He was the community leader of the Evapotranspiration (ET) measurement and modeling community in the American Society of Agronomy (ASA) where he has organized several sessions and symposiums on ET. Presently he is the Vice Leader of Global Climate Change community in ASA. He is also the member of ASCE-EWRI-ET in Irrigation and Hydrology Technical committee where he is assisting in the development of FAO-56 manual for remote sensing based ET estimation.

George's work on assessing the impacts of climate change and variability on crop production and hydrological processes has garnered huge interest among stakeholders and the scientific community. In particular, his work focused on the U.S.'s Ogallala aquifer region, consisting of 232 counties spread over eight states, has demonstrated that proper crop management decisions, genetic improvements, and carbon dioxide fertilization will compensate for yield losses. He developed a GIS-crop model-climate scenario framework for the Ogallala aquifer region, which informed decision makers and policy makers on long-term strategies to cope with impacts of climate change and variability on water use and crop production. Dr. Paul is a key contributor in identifying pathways to improve adaptation to climate variability and change; through his systems modeling capabilities, he integrated components of agricultural landscapes, including soil, water, atmosphere, vegetation, livestock, and management, into a framework capable of operating at various scales.

Representative Project Experience

Time Series Daily Evaporation, Transpiration and Evapotranspiration Maps from Landsat Satellite Remotely Sensed Data Using Two Source Energy Balance Model (2010-present)

In this project George developed a framework for generating high resolution daily ET maps from Landsat data. The Two Source Energy Balance Series Model was used to compute sensible and latent heat fluxes of soil and canopy separately. Landsat 5 (2000-2011) and Landsat 8 (2013-2014) imageries for path row 28/35 and 27/36 covering forage–rangeland–winter wheat production systems within the State of Oklahoma were utilized. An extensive network of weather stations managed by Oklahoma Mesonet was used to generate spatially interpolated inputs of air temperature, relative humidity, wind speed, solar radiation, pressure, and reference ET. Several new parameters were developed by George to improve the performance of TSM model including an atmospheric correction algorithm, function for varying Priestley-Taylor's coefficient, and a daily reference ET based extrapolation algorithm. Accuracy assessment of daily ET maps was done against eddy covariance data indicated good performance of the modeling framework. Results indicated that the proposed ET mapping framework is suitable for deriving high resolution daily time series ET maps at regional scale with Landsat visible and thermal data.

Statistical and Remote Sensing Approaches to Automate Hot and Cold Pixel Selection for Surface Energy Balance Based Evapotranspiration Mapping (2010-2012)

In this project, George first establish the inherent uncertainty generated from the 'hot' and 'cold' pixel approach in the estimation of Evapotranspiration and then used it as a benchmark for the evaluating a novel statistical-spectral automated approach. Existing hot and cold pixel selection methodologies in surface energy balance models are subjective and provide different results to different users. The approach of hot and cold pixel is an empirical method for estimating the 'dT' parameter over a relatively homogeneous and well managed landscape for implementing single source energy balance models such as SEBAL and METRIC. George developed a novel methodology for the selection of hot and cold end member pixels to make the application of single source energy balance models more robust.

Assessing Impact of Climate Variability and Climate Change on Crop Production in Ogallala Aquifer Region. (2008-2010)

The work funded by USDA Ogallala initiative was conceptualized and executed by George. The study assessed the impact of A2 climate scenario with fine resolution Regional Climate Model (RCM) on the crop production using CERES-Sorghum and CERES-Wheat crop simulation models. Three RCM's were utilized to account for the uncertainties inherent among various climate models. Analysis showed that the Ogallala region will experience warmer temperatures and temporal shifting of precipitation patterns. Increase in temperature of 4-5°C is seen in future climate with decreased summer season precipitation. George showed that Grain Sorghum production in the region will decrease by 40-50%, however proper management decisions, genetic improvements and carbon dioxide will negate these yield loss. Future climate may be conducive for wheat production and an increase of 45% in grain yields are predicted for this region. The study provided the crucial information on the magnitude of change that could be expected in the future climates. The information generated from the crop simulations is being used by decision/policy makers to device long-term strategies to cope with impacts of climate change and variability on water use and crop production.

Mark J. Roberson, PhD, CPSS
Senior Soil Chemist / Irrigation Water Management Specialist

Education: BS Biochemistry 1986 University of California
MS Soil Science/Agricultural Engineering 1992 Cal Poly San Luis Obispo
PhD Soil Chemistry 1998 University of California

Dr. Roberson is a Senior Soil Chemist/Irrigation Water Management Specialist with Formation Environmental LLC. He has 23 years of irrigation, drainage, and water quality experience. His initial experience with agricultural water quality was from an internship on a 3,000-acre farm in the Imperial Valley. As a Senior Water Management Specialist for the Imperial Irrigation District, he participated in the implementation of the Imperial Irrigation District - Metropolitan Water District water conservation agreement including impacts to the Salton Sea. To further his technical knowledge of irrigation and drainage water quality, he studied as a USDA National Need Fellow and obtained a Ph.D. in soil chemistry. He has a comprehensive understanding of irrigation district operations, on-farm water management and drainage, particularly from the perspective of water quality. Dr. Roberson's academic training provides him with a thorough knowledge of soil and water chemistry as well as soil-water interactions. He has served as consulting staff for local, state, and federal agencies. In addition, he has provided consulting services for private clients.

As a soil chemist, Dr. Roberson has participated in several water quality technical studies and processes involving the Central Valley of California. Studies include the preparation of an assessment of the impacts to soil salinity from ocean water inundation in the Delta, the identification of water quality impairments to the Stockton Deep Water Ship Channel, an assessment of management practices on irrigated lands in the Central Valley, assessed salinity impacts on agricultural lands, and the preparation of water quality reports for the Colorado River region. Dr. Roberson has served on the UC Salinity and Drainage task force and has reviewed a significant number of water quality grant proposals for the State Water Resources Control Board, the US Bureau of Reclamation, the Department of Water Resources, the Natural Resources Conservation Service and the Natural Resources Agency.

As an irrigation water management specialist Dr. Roberson has provided irrigation scheduling and water management support to growers, urban water agencies, the Bureau of Reclamation, and several California state agencies including the Department of Water Resources, the State Water Resources Control Board and the Central Valley Regional Quality Control Board. Water management support has included the use of remotely sensed ET data, developed through the surface energy balance algorithm for land (SEBAL). This information has been used to quantify ET on irrigated and non-irrigated lands. Non-irrigated lands have included riparian areas, wetlands, and upland rangelands. Other uses of SEBAL have included quantify irrigation efficiency, salinity impacts, and quantifying water use by crops under different irrigation methods.

Dr. Roberson's dissertation topic was the use of zero-valent iron for the removal of selenate from irrigation drainage water. During his studies he identified several important operating variables and environmental conditions necessary for optimizing the chemical reduction of selenate. In addition, he completed a system mass balance and analyzed the end products using x-ray adsorption near edge spectroscopy at the Stanford Linear Accelerator for chemical speciation of selenium. Chemical speciation models used for data analysis included MINTEQ, FITEQ and GEOCHEM.

Representative Project Experience

Imperial Irrigation District, Imperial County California (1991-1995 and 2014 to present)

Salton Sea - Air Quality Mitigation Program Design: As part of the Imperial Irrigation District's (IID) efforts to implement the Water Transfer Mitigation and Monitoring Program, Dr. Roberson provides technical and program management services to IID. He serves as project manager, coordinating efforts with IID. In this capacity, he is working to implement tillage operations around the Salton Sea to identify useful dust control operations.

Water Department – Irrigation Management Unit: For the Imperial Irrigation District (1991-1995) Mr. Roberson served as a Senior Water Management Specialist in the Irrigation Management Unit. His primary duty was to work with the farmers to promote cost-effective water conservation technologies and improved water management techniques. He developed low-cost, automated water measurement and data logging devices that were used to provide real time water management information to growers. Also, he developed a set of portable water measurement devices that were used to monitor irrigation events. Both types of water measurement devices were supported with customized, spreadsheet-based reporting routines.

Colorado River Regional Water Quality Control Board (2007-present)

For the Colorado River Regional Water Quality Control Board Dr. Roberson is currently analyzing and reporting on the monitoring data collected for the Surface Water Ambient Monitoring Program (SWAMP) for the reporting period of spring 2009 to fall 2013. In addition, he prepared the Board's 2007 and 2009 SWAMP reports. Data types analyzed include field measurements, results of laboratory testing for constituents, and toxicity analysis. These documents are used to guide Basin Plan formulation and other Board policies.

Central Valley Regional Water Quality Control Board (2005-2013)

For the Central Valley Regional Water Quality Control Board Dr. Roberson conducted the technical analysis for the development of the Irrigated Lands Regulatory Program. This Program is designed to reduce water quality impacts to both surface and ground water in the Central valley of California. In addition to developing the program Dr. Roberson provided peer review of the Waste Discharge Requirements developed for several of the coalitions.

San Joaquin River Restoration Program (2012)

Dr. Roberson was a member of a multi-disciplinary peer review panel for the Seepage Management Plan of the San Joaquin River Restoration Program. This effort required document review, public input and the preparation of a report. Findings of the review were used to inform the implementation policy of the restoration effort.

Other Select Experience (2001-2007)

For a Sacramento Valley vegetable oil extractor Dr. Roberson prepared the soil and water portion of their wastewater discharge permit as required by the California Regional Water Quality Control Board. This work involved reviewing criteria for land disposal of processing effluent, reviewing the soil's capacity to contain the waste, and analyzing chemistry of the discharge effluent. In addition a management plan was prepared to use the effluent for irrigation of several agronomic crops.

For a golf course in Colorado Dr. Roberson interpreted a chemical analysis of the water used for irrigation. The facility had several wells with differing water quality and they were proposing the development of several new wells. In addition a management plan was prepared for blending and using the water for irrigation.

Marty Petach

Senior GIS Analyst

Education: **M.S., Soil Physics, Cornell University, 1989**
 B.S., Soil and Water Science, University of California, Davis, 1985

Mr. Petach has over 26 years experience using Geographic Information Systems (GIS) to analyze and display spatial and temporal trends for a broad range of environmental issues at a wide variety of client sites. His background in soil physics is valuable for resolving technical issues involved in complex data analyses.

He builds and populates environmental sampling databases using MS Access, PostGRES, and SQL databases, and develops spatial datasets using the ArcGIS and the Open GIS Consortium (OGC) PostGIS suite of tools. These databases can involve hundreds of chemicals, thousands of sampling locations, and millions of analytical results on large projects. He uses GIS to efficiently manipulate spatial data, including: interpolation of point sampling data to continuous surfaces; spatial intersection of multiple datasets such as ownership, vegetation and chemical concentration in soils; volumetric calculations; and image analysis and pattern extraction from remotely sensed data. Using the GIS to perform precise statistical analysis and accounting is also one of Mr. Petach's areas of expertise, and he writes customized computer programs to automate and document such data manipulations, especially for litigation projects.

He uses GIS to focus and simplify complex patterns at projects sites, and to depict pertinent site conditions in an effective manner to appropriate audiences, including: clients, project managers, agency personnel, and citizens at public meetings. Mr. Petach uses GIS to produce high quality maps, technical animations, PDF files, and interactive web sites to convey site conditions. He serves as a technical expert on litigation cases.

Representative Project Experience:

WATERSHED WATER QUALITY ASSESSMENTS AND AGRICULTURAL SYSTEMS

Southern Nevada - Assisted in development of hydrogeologic groundwater flow model that spans 3 states and contains over a million model cells. Produced tools to rapidly visualize and check model input data, and tools to visualize model output using 3D viewing environments, including Google Earth Enterprise. Developed runoff-flow-routing algorithms, and created programs to automatically generate over 500 cross-section maps with linked plan and profile views.

Eureka, California - GIS coordinator for 40,000 acre watershed assessment for the timber industry;

Coeur d'Alene Basin, Idaho - GIS database administrator of a 25-gigabyte dataset developed to support a Natural Resources Damage claim involving heavy metals in a 6,000-square mile watershed and Superfund Site;

Panoche/Silver Creek Watershed, California - Developed GIS-based sediment and water quality assessment using AGNPS and KINEROS models, and Arc/Info for a large watershed;

NIWA, New Zealand - Used GIS to assess non-point source pollutant loadings for agricultural, native forest and plantation forest land uses within New Zealand;

Troy, New York - Estimated pesticide leaching to groundwater in spatially variable agricultural soils using a National Science Foundation (NSF) supercomputer, a GIS, and the LEACHM solute transport model. Wrote and used programs to pre- and post-process data, translate formats, control model execution, analyze results, and produce animations of model output.

ENVIRONMENTAL IMPACT ASSESSMENT AND LANDUSE PLANNING

Rocky Flats Plant Site, Colorado - Incorporated air quality modeling results from radionuclide exposure model into GIS in support of the Sitewide Environmental Impact Statement (SWEIS) at the

Rocky Flats Plant (RFP). Used GIS to compute the total estimated dose from multiple radionuclides originating from multiple spatially distributed sources.

Confidential Client - Developed web-based interface that integrates several large air quality GIS datasets and authored an associated interactive time-series charting tool, spatial mapping engine, and data downloader.

Breckenridge Ski Area - Assisted with development of 2007 Breckenridge Trail Map. Produced perspective view 3D map using real data including current winter-time satellite imagery draped over a highly detailed digital elevation model. Buildings and roads were extracted using eCognition / Definiens Developer image processing software.

Union Pacific Railroad, Idaho - Used GIS to support the conversion of 72 miles of former mining railroad right-of-way to a recreational use facility. He used GIS to develop ownership, railroad facilities, hydrography, and facility layers for the trail.

Aquatic & Wetlands Consultants, Colorado - Performed habitat mapping to support a planned ski resort and Planned Unit Development (PUD) in Colorado. Computed areas of habitat affected for multiple development options. Generated three-dimensional visualizations of the proposed ski area.

MINING

Conda Mine, Idaho; J.R. Simplot Company - Assessed impacts to water quality; Created 3D interactive visualizations of subsurface hydrogeologic conditions at a former phosphate mine including water chemistry, groundwater and surface water flowpaths, geologic units and faults using GIS, Google SketchUp, and Google Earth;

Freeport McMoran, Irian Jaya, Indonesia - Identified large areas of vegetation affected by mining discharge in the vicinity of an active gold mine using satellite imagery. Used Thematic Mapper satellite image data to provide base maps in regions with no detailed maps.

Anaconda, Montana - Developed interactive web application allowing project managers to zoom, pan, and query sampling results for soil, surface water, groundwater at a former smelter site. The web-based application incorporates GIS layers for aerial photographs, site infrastructure, sampling locations, remedial action areas, institutional controls, and deed restrictions.

Omaha, Nebraska - Utilized GIS to elucidate lead deposition patterns and identify co-varying lead-based paint impacts at a former smelter site.

SEDIMENT

Port of Portland, Oregon - Developed GIS data layers, chemical databases, and custom programs to evaluate natural resources injury from multiple chemical constituents in sediments located in the Portland Harbor Superfund Site and other contaminated locations along the Lower Willamette River.

Puget Sound Tributary Waterway - Used GIS for a PRP CERCLA Response Action allocation issue related to PCB sediment contamination in a Puget Sound Tributary Waterway.

PAST WORK HISTORY

Senior GIS Analyst/Partner - Formation Environmental (2009-present)

Senior GIS Analyst/Partner - NewFields (2004-2009)

GIS Analyst - MFG, Inc. (1999-2004), (1996-1998)

Programmer - National Center for Atmospheric Research in Boulder, Colorado (1998-1999)

Analyst - National Institute of Water and Atmospheric Research (NIWA), Hamilton, New Zealand (1992-1994)

Education

MS, Bioresource Engineering, Oregon State University, 1998

BS, Soil Science, Evergreen State College, 1993

Professional Registration

Professional Engineer: Oregon, Washington

Certified Professional Soil Scientist

Certified Water Rights Examiner: Oregon

Distinguishing Qualifications

17 years experience as a consulting soil scientist and agricultural engineer

Experience on over 50 projects involving agricultural, landscape, and forestry reuse of wastewater and residuals

Nutrient management experience over a wide range of municipal and industrial recycled water, residuals, and manure applications

Experience Prior to CH2M HILL

Research assistant at Oregon State University, 1995-1997. Worked with farmers to reduce the impacts of nitrate and pesticide loading to groundwater under agricultural production through improved irrigation and nutrient management. Designed and conducted agronomic field experiments; obtained grant funding for on-farm research; and provided outreach to farmers. Coordinated meetings, workshops, and presentations between farmers, crop consultants, and the research team.

Professional Organizations/Affiliations

U.S. Committee on Irrigation and Drainage

American Society of Agricultural and Biological Engineers

Soil Science Society of America

Professional Responsibilities

Oregon State University – Industry Advisory Board for Ecological Engineering, 2010 to Present

Oregon Water Trust—Board of Directors, 2006 to 2008

GENERAL EXPERIENCE

Mr. Smesrud is a principal soil scientist and agricultural engineer with CH2M HILL's Water Business Group. He also serves as the firm-wide technology leader for Agricultural Services at CH2M HILL. Mr. Smesrud's consulting experience involves water resources planning, irrigation and drainage system design and water management, soil salinity and nutrient management, and engineering of soil/plant systems for natural treatment system projects. Mr. Smesrud has served as project manager, design manager, and senior consultant on numerous projects through the planning, permitting, design, construction, and operations phases in the US, Middle East, and Latin America.

For the SSJV MPEP, Mr. Smesrud's primary contribution to the team would be in irrigation and drainage system assessment and vadose zone monitoring and modeling. For these capabilities, Mr. Smesrud has designed and overseen the operations of a wide range of irrigation and drainage systems including drip/micro, sprinkler, and flood irrigation systems and tile drainage systems and is currently working with other clients on the assessment of current and future trends in on-farm irrigation practices in the SJV. Starting with his graduate research on nitrate leaching under agricultural production and continuing on several permitted land application projects, Mr. Smesrud has also developed significant experience in the design, installation, and operation of vadose zone monitoring systems such as wick and suction lysimeters and a wide array of soil moisture sensors along with the modeling of vadose zone processes.

REPRESENTATIVE PROJECT EXPERIENCE

Senior Consultant; San Pasqual Basin Salt and Nutrient Management Plan; City of San Diego, CA. Led the characterization and assessment of agricultural uses, nutrient contributions, and water demands across this basin and was the lead author on future agricultural management strategies. Developed nutrient budgets for each major land use, GIS based analytical models for basin wide groundwater pumping, consumptive use, and return flow estimates, and coordinated efforts of groundwater modeling to help define future water quality management strategies. Also developed the future BMP implementation plans around NRCS standards.

Senior Consultant; Water Resources Management Plan; Merced Irrigation District, CA. Led the on-farm systems assessment and water balance components of a comprehensive forward looking management plan. The purpose of this plan is to ensure the future water supply and financial sustainability of the district which serves 130,000 acres of highly productive agricultural land. Work under the on-farm efforts included farmer interviews, detailed land use assessments, remote sensing analysis of cropping systems, and characterization of on-farm management practices. The water balance efforts integrated the on-farm work along with detailed assessments of district infrastructure and water delivery operations within a systems dynamics model to evaluate all District water supplies, demands, return flows, and losses.

Senior Consultant; Sacramento Valley Groundwater Quality Assessment Report; Northern California Water Association, CA. Provided technical review and guidance for assessment and initial screening on-farm practices with respect to nitrate leaching. The nitrate hazard index tool was used for this initial screening evaluation in combination with other hydrogeological information.

Senior Consultant; Modesto Wastewater Treatment Plant Land Application System Evaluation; City of Modesto, CA. Led the independent review of land application facilities operations over the 2,500-acre Jennings Ranch to determine whether loading rates of cannery process water could be increased. The evaluation included facility and Ranch staff interviews; analysis of hydraulic, nutrient, and salt loading rates and soil and groundwater monitoring data; evaluating crop and soil management practices; and identifying and ranking viable alternatives for increasing cannery flows to the Ranch.

Project Manager; Gas Fired Power Plant Cooling Water Irrigated Reuse Program; Hermiston Generating, OR. Conducted permit negotiations with regulatory agencies and prepared Operation, Maintenance and Management plans and annual reports for the blended saline cooling water irrigation program over 700 acres of commercial crop land (alfalfa, wheat, peas, canola, corn, potatoes). Work included evaluating crop irrigation water and nutrient demands and salinity limitations, providing irrigation scheduling feedback, and evaluating soil moisture monitoring as part of the permitted reuse operations.

Project Manager; EQIP Irrigation Water Conservation Projects; Natural Resources Conservation Service; OR. Developed on-farm irrigation system designs for flood irrigation conversions on four separate farms, including pasture, vegetable crop, and orchard systems. Designs included site surveys, landowner interviews, soil and crop evaluation, field flood tests, and hydraulic modeling. Prepared comprehensive design reports, construction drawings and specifications, and irrigation water management plans. Oversaw construction, and certified completed conservation practices upon system startup.

Project Manager; Agricultural Phosphorus Water Quality Trading Program Review; The Freshwater Trust; OR. Provided independent technical review of on-farm phosphorus reduction estimates, BMP costs, and potential implementation barriers to initiating on-farm nutrient reduction practices in the Klamath Basin.

Senior Consultant; Odessa Subarea Irrigation Replacement Project EIS Salinity and Sodicity Assessment; Bureau of Reclamation; Odessa, WA. Led the evaluation of irrigation water salinity and sodicity impacts to agricultural production costs for this groundwater replacement project serving over 100,000 acres of pivot irrigation to potatoes, corn, peas, wheat, and alfalfa. Work involved characterization of water quality, soils, and cropping systems, farmer interviews and development of a salinity and sodicity impact assessment to substantiate the project socio-economic analysis.

Project Manager; Recycled Water and Biosolids Management Plans; Woodburn, OR. Developed plans to guide the management of water and nutrients from recycled water and biosolids applications to approximately 80 acres of poplar trees and 1000 acres of grass seed and grain fields in accordance with DEQ regulations.

Senior Consultant; Laguna Sanitation District Golf Course Salinity Management Evaluation, Santa Maria, California. Led the work to develop salinity and nutrient management solutions for transitioning a local golf course from groundwater to a municipal recycled water supply for irrigation. Work involved interviews of recycled water purveyor/users across the S. CA coast to assess TDS ranges and salinity management approaches utilized on other golf courses receiving recycled water.

Senior Consultant and Design Engineer; Cellulosic Ethanol Feedstock Farm Development; Confidential Client; Texas. Led soil investigations, irrigation design criteria development, and irrigation designs for pumped furrow irrigation of 4,500 acres of cropland being converted from rice to energy cane biomass cropping. Worked with farmers and operators throughout design process to provide simple, reliable, and cost-effective designs.

Senior Consultant, Design Manager, and Design Engineer; Owens Lake Dust Mitigation Program; Los Angeles Department of Water and Power; Inyo County, CA. Served as design engineer, design manager, and senior consultant for various aspects of irrigation and drainage facility development over 19,000 acres of dry saline lakebed during the course of 7 years and 5 phases of development. Responsibilities included design document development, services during construction, operations and regulatory support, and operational capacity building for a highly automated flood irrigation, drip irrigation, and subsurface drainage system development. Worked as part of a multi-agency operations team evaluating the effectiveness and reliability of irrigation and drainage operations and developing operational support tools.

Curriculum Vitae - Kenneth G. Cassman

- Biographical sketch:** Dr. Cassman is a systems agronomist who has worked on nearly every major crop production system worldwide, including temperate and tropical, humid to arid, irrigated and rainfed. He is best known for work on improving nitrogen fertilizer efficiency¹ and ecological intensification².
- Current Position:** Half-time appointment as professor, University of Nebraska, and agricultural consultant specializing in: (i) diagnosis and alleviation of constraints to improved crop and soil management that optimize production, profit, and environmental quality, and (ii) strategic planning and research prioritization for universities, research institutions, and government agencies.
- Phone/email:** Phone: (402) 613-9888, Email: kgc1consulting@gmail.com
- Areas of expertise:** Plant nutrition, soil fertility, nutrient cycling; energy efficiency, life-cycle assessment, environmental impact of biofuels; global food security; scientific administration, strategic planning and research prioritization.
- Education:**
- | | |
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| Postdoctoral Fellow, University of California Davis | 1979-1980 |
| Ph.D. (Agronomy and Soil Science) University of Hawaii | 1979 |
| B. Sc. (Biology) University of California San Diego | 1975 |
- Previous Positions:**
- | | |
|---|-----------|
| Professor and Systems Agronomist, University of Nebraska | 2011-2015 |
| Chair, Independent Science and Partnership Council, Consultative Group for International Agric. Research (sciencecouncil.cgiar.org) | 2011-2013 |
| Director, Nebraska Center for Energy Sciences Research | 2006-2010 |
| Heuermann Professor of Agronomy, Univ Nebraska-Lincoln (UNL) | 2004-2006 |
| Dept. Head and Professor, Dept of Agron. and Horticulture | 1996-2004 |
| Head, Division of Agronomy, Plant Physiology, and Agroecology, International Rice Research Inst., Los Baños, Laguna, Philippines | 1991-1995 |
| Assist./Assoc. Professor, Dept. Agronomy and Range Sci., UC Davis | 1984-1991 |
| Agronomist, Egyptian Major Cereals Improvement Project, Egypt | 1982-1984 |
| Project Leader, Amazon Rice Res. Station, San Raimundo, Brasil | 1980-1982 |
- Consultancies:** (since 2009)
- | | |
|---|--------------|
| Ingleby Farms and Forests (http://inglebyfarms.com/), member of the Environmental Advisory Committee and sustainability consultant | 2009-present |
| AGREE ag policy think tank (http://www.foodandagpolicy.org/), Member of Research Advisory Committee | 2011-2013 |
- Honors & Awards:**
- | | |
|--|------|
| President's Career Achievement Award, Crop Sci. Soc. America | 2012 |
| Justin Smith Morrill Lecture, Assoc. of Public Land-Grant Universities | 2011 |
| Agronomic Research Award, American Soc. of Agronomy | 2006 |
| Fellow, American Assoc. for the Advancement of Science (AAAS) | 2005 |
| Weston Distinguished Lecture, Univ. of Wisconsin SAGE Program | 2005 |
| International Crop Nutrition Award, International Fertilizer Assoc. | 2004 |
| Outstanding Alumnus, College of Tropical Agric., Univ. of Hawaii | 2003 |
| Robert E. Wagner Award, Potash and Phosphate Institute | 2000 |
| Fellow, Crop Science Society of America | 1999 |
| Research and Education Award, Nebraska Agric. Business Assn. | 1998 |
| Fellow, Agronomy Soc. of America & Soil Science Soc. Of America | 1996 |
- Honors & Awards:** (continued)

¹ https://scholar.google.com/scholar?q=fertilizer+nitrogen+use+efficiency&btnG=&hl=en&as_sdt=0%2C5

² https://scholar.google.com/scholar?q=fertilizer+nitrogen+use+efficiency&btnG=&hl=en&as_sdt=0%2C5

M.S. Swaminathan Outstanding Research Award, Philippine Council for Agriculture & Natural Resources Res. & Development	1996
Researcher of the Year, Fluid Fertilizer Foundation	1989
Professional Societies: Soil Science Society of America	since 1977
American Society of Agronomy	since 1977
Crop Science Society of America	since 1977
American Association for the Advancement of Science	since 2001
Current roles in Editorial Boards:	
Editor-in-Chief, Global Food Security www.journals.elsevier.com/global-food-security	since 2012
Selected Professional Activities and Service:	
Scientific Organizing Committee: First International Conference on Global Food Security (http://www.globalfoodsecurityconference.com/)	2012-2013
European Union, Joint Planning Initiative—Food, Agric., Climate Change	2010-2012
US-EPA Science Advisory Comm., Integrated Nitrogen Management	2007-2009
Coordinating Lead Author, Cultivated Systems Chapter, Millennium Ecosystem Assessment	2003-2005
Science and Policy Committee, 3 rd International Nitrogen Conference	2002-2004
North Central State Research Advisory Committee, USDA—CSREES	1996-2004
Nebraska Crop Improvement Association, Board of Directors	1997-2004
External Review Panel, Dept. of Soil Science, Univ. of Wisconsin	1999
Nebraska Certified Crop Advisors Executive Board, A092 ARCPACS Committee	1996-2002
Major Research Grants (partial list, since 2001):	
2014-2015 Bill & Melinda Gates Fd, Global Yield Gap Atlas for SSA	\$1,225,000
2013-2015 USAID, Global Yield Gap Atlas for the Middle East	\$ 470,000
2011-2013 Bill & Melinda Gates Fd, Global Yield Gap Atlas for SSA	\$2,100,000
2006-2011 Nebraska Public Power: UNL Energy Center grant program	\$5,000,000
2009-2010 Water, Energy and Agriculture Initiative	\$ 450,000
2007-2010 U.S. DOE—BER: Carbon sequestration in agroecosystems	\$1,000,116
2007-2010 USDA-NRCS: Limited Irrigation Systems for Corn	\$231,500
2001-2006 U.S. DOE—BER: Carbon sequestration in agroecosystems	\$2,900,000
Teaching:	
Supervised 13MSc and 12 PhD students at UC Davis, IRRI/UPLB, and UNL	
Courses taught: <i>Analysis and Determinants of Cropping Systems</i> , UC Davis, 1984-1990	
Publication summary (1972-2012)	
Books and special publications	10
Refereed journal articles	164
Book chapters, conference symposia, reviews, editorials	52
Copyright software programs and models	5
Extension, government, and industry publications	13

Publications available upon request.